PB84-102540

Human Exposure to Atmospheric Concentrations of Selected Chemicals. Volume 1

Systems Applications, Inc., San Rafael, CA

Prepared for

Environmental Protection Agency
Research Triangle Park, NC

Sep 83

U.S. Department of Commerce
National Technical Information Service
NTIS

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO. N.A.	**2.**	**3. RECIPIENT'S ACCESSION NO.** PB84 102540
4. TITLE AND SUBTITLE Human Exposure to Atmospheric Concentrations of Selected Chemicals Vol. I		**5. REPORT DATE** September 1983 (Date of Approval **6. PERFORMING ORGANIZATION CODE**
7. AUTHOR(S) Gerald E. Anderson		**8. PERFORMING ORGANIZATION REPORT NO.**
9. PERFORMING ORGANIZATION NAME AND ADDRESS Systems Applications, Incorporated 101 Lucas Valley Road San Rafael, California 94903		**10. PROGRAM ELEMENT NO.** **11. CONTRACT/GRANT NO.** EPA No. 68-02-3066
12. SPONSORING AGENCY NAME AND ADDRESS U.S. Environmental Protection Agency Strategies and Air Standards Division Office of Air Quality Planning and Standards Research Triangle Park, N.C. 27711		**13. TYPE OF REPORT AND PERIOD COVERED** Interim **14. SPONSORING AGENCY CODE**

15. SUPPLEMENTARY NOTES

Supercedes PB81-193252 and PB81 193260

16. ABSTRACT

EPA commissioned Systems Application, Inc.(SAI) to estimate, on a nationwide basis, public exposure to atmospheric concentrations of some forty chemicals. The purpose of the study was to provide EPA with information that would be helpful for determining which of the chemicals to study in more detail and in what order. The emphasis was on estimates that would support rough relative comparisons among the chemicals. There was no intent to define, by a scientifically defensible methodology, actual public exposure and actual ambient air concentrations; the purpose did not warrant the very heavy expenditure of funds that would be needed to carry our such a project. The study made free use of such techniques as algorithms for estimating emissions rather than actual emissions data, constructed plant locations rather than actual plant locations, simplified dispersion modeling to estimate ambient air concentrations, and a constructed "population" file that relied on extrapolation of 1970 Bureau of Census data on where people lived.

The original version of the report, dated May 6, 1980, was, in March 1981, made available for public review and comment. The current, and final, version of this report reflects the comments and data received and incorporated changes made to correct technical deficiencies, noted by SAI and EPA, in the previous version.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Exposure Air Pollutants	Atmospheric Dispersion Model, Human Population Exposure	

18. DISTRIBUTION STATEMENT Release Unlimited	**19. SECURITY CLASS** *(This Report)* None	**21. NO. OF PAGES**
	20. SECURITY CLASS *(This page)*	**22. PRICE**

EPA Form 2220-1 (9-73)

PB84-102540

SAI

Human Exposure To Atmospheric Concentrations Of Selected Chemicals

Volume I

Office of Air Quality Planning and Standards
Environmental Protection Agency
Research Triangle Park, North Carolina 27711

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

HUMAN EXPOSURE TO ATMOSPHERIC CONCENTRATIONS OF SELECTED CHEMICALS

EPA Contract No. 68-02-3066

SAI No. 58-EF81-156R2

Prepared for

Office of Air Quality Planning and Standards
Environmental Protection Agency
Research Triangle Park, North Carolina 27711

by

Systems Applications, Incorporated

Amended by EPA

to reflect public comments

March 1983

PREFACE

In 1979, EPA commissioned Systems Application, Inc. (SAI) to estimate, on a nationwide basis, public exposure to atmospheric concentrations of some forty chemicals. The purpose of the study was to provide EPA with information that would be helpful for determining which of the chemicals to study in more detail and in what order. The emphasis was on estimates that would support rough relative comparisons among the chemicals. There was no intent to define, by a scientifically defensible methodology, actual public exposure and actual ambient air concentrations; the purpose did not warrant the very heavy expenditure of funds that would be needed to carry out such a project. The study made free use of such techniques as algorithms for estimating emissions rather than actual emissions data, constructed plant locations rather than actual plant locations, simplified dispersion modeling to estimate ambient air concentrations, and a constructed "population" file that relied on extrapolation of 1970 Bureau of Census data on where people lived.

The original version of the report, dated May 6, 1980, was, in March 1981, made available for public review and comment. The current, and final, version of this report reflects the comments and data received and incorporates changes made to correct technical deficiencies, noted by SAI and EPA, in the previous version.

During the public review of the previous version, some persons created substantial misunderstandings of the report by using it to support publicized claims of serious public health hazards.

This final version of the report, while it contains some improved information and is hopefully free of glaring errors of fact, is still by intent and design useful only for making rough comparisons among the selected chemicals.

The information is not intended to nor can it sensibly be used to support conclusions regarding risks to public health.

CONTENTS

PREFACE.. i

FIGURES.. iii

TABLES.. iv

1. EXECUTIVE SUMMARY.. 1

2. DATA BASES.. 26
   Emissions Data.. 26
   Meteorological Data.. 35
   Population Distribution Data Bases.. 44
   Atmospheric Transformations of Toxic Compounds.. 54

3. EXPOSURE-DOSAGE APPROACH.. 84
   Major (Specific) Point Sources.. 84
   Prototype Point Source Exposure and Dosage Estimations.. 110
   Area Source Modeling Approach.. 144

4. UNCERTAINTIES.. 193
   Uncertainties Involved in Emissions Estimations.. 193
   Uncertainties in Exposure/Dosage Estimations.. 194

REFERENCES.. 216

ATTACHMENTS

A Summary of Human Exposure Estimations for 35 Selected Chemicals.. A-1

B Supplementary Document for Human Exposure Estimations.. B-1

FIGURES

Number Page

1 U.S. Georgraphic Regions.................................... 16

2 STAR Station Selection Process Map I........................ 80

3 STAR Station Selection Process Map II....................... 81

4 STAR Station Selection Process Map III...................... 82

5 STAR Station Selection Process Map IV....................... 83

6 Effects of Chemical Reactivity on Concentration Distribution of Chloroprene............................ 88

7 Effect of Building Wake on Concentration Distribution of Chloroprene.. 90

8 Impacts of Release Height on Concentration Distribution of Chloroprene.. 91

9 Schematic Illustration of Virtual Point Source Concept...... 101

10 Reference Points for an ED/BG Centroid..................... 108

11 U.S. Urbanized Areas (1970)................................ 112

12 U.S. Standard Metropolitan Statistical Areas (1970)......... 136

13 U.S. Standard Metropolitan Statistical Areas (1970)......... 137

TABLES

Number		Page
1	List of Chemicals for Human Exposure/Dosage Estimation	6
2	Rank Order Listing of Chemicals by Total Emissions	20
3	Studied Chemicals Ranked by Estimated Total U.S. Dosage	21
4	Example of location of Chemical-Emitting Sources	40
5	Selected STAR Stations for PCB Incinerators	43
6	Selected Regional Prototype Star Stations with Representative Regional Climatological Conditions	45
7	Distribution of ED/BGs with Population Centroids Located outside Their Corresponding Counties	52
8	Decay Rate Estimation Categories for 25 Chemicals	58
9	Photochemical Reactivities of Selected Chemicals	62
10	Location and Recording Period of STAR Stations in the Reprocessed File	64
11	Location of Selected STAR Station of Specific Point Sources	72
12	Pasquill-Gifford Stability Classes Used in Point Sources Analysis	94
13	Sequence of Input Data Cards for Program GAUSS	100
14	Chloroprene Concentration Pattern around the Denka Plant at Houston	106
15	Nationwide Trichloroethylene Emissions from Solvent Degreasers	111
16	1970 Population Density and Number of Trichloroethylene-Using Degreasers in the Nine Geographic Regions	114
17	Major Parameters and Concentration-Dosage Results of Uniform Emissions Approach	115
18	Emissions Parameters for Generic Point Sources of Trichloroethylene	117

Number Page

19 Trichloroethylene Concentration Pattern around a Model Open Top Vapor Degreaser in New England Region............. 118

20 Land Areas for Specified Concentration Centers............... 119

21 Population Exposure to Trichloroethylene Emitted from a Model Degreaser.. 122

22 Trichloroethylene Dosage Resulting from a Model Degreaser Emissions.. 125

23 Nationwide Trichloroethylene Dosage Resulting from Emissions from Degreasing Operations....................... 130

24 Nationwide Trichloroethylene Dosage Resulting from Emissions from Degreasing Operations....................... 131

25 Nationwide Trichloroethylene Exposures and Dosages Resulting from Emissions from Different Types of Degreasing Facilities....................................... 132

26 Major State Statistics Related to Area Source Emissions Distribution.. 141

27 Major Parameters for Estimating Exposure/Dosage Resulting from Area Source Emissions of Beryllium................ 145

28 Beryllium Exposure and Dosage Resulting from Area Source Emissions in Type I Cities......................... 146

29 Beryllium Exposure and Dosage Resulting from Area Source Emissions in Type II Cities........................ 158

30 Beryllium Exposure and Dosage Resulting from Area Source Emissions in Type III Cities....................... 165

31 Summary of Beryllium Exposure and Dosage Resulting from Area Source Emissions.. 169

32 Exposure/Dosage Analysis Data Base for Type I City Area Sources.. 170

33 Exposure/Dosage Analysis Data Base for Type II City Area Sources.. 182

34 Exposure/Dosage Analysis Data Base for Type III City Area Sources.. 189

35 Definition of Uncertainty Levels in Chemical Source Locations and Emissions Estimations........................ 196

36 Levels of Uncertainty for Assessed Chemicals................. 197

Number Page

37 Percentage of Change in Dosage from Base Case Resulting from Location Shift.............................. 214

38 Percentage of Change in Exposure from Base Case Resulting from Location Shift.............................. 214

SECTION 1

EXECUTIVE SUMMARY

INTRODUCTION

Recent federal legislation has responded to the increased public awareness of and concern about the public health danger of man-made chemicals in the environment. These laws have, in turn, placed more responsibility on the Environmental Protection Agency (EPA) to assess the need for regulatory control over the sources of these chemicals. Assessment of the need for additional control requires information about the chemicals, their interaction with the environment, and their health impacts on the human population. As part of a continuing effort by the EPA to fulfill this information need, the Strategies and Air Standards Division of the EPA's Office of Air Quality Planning and Standards has commissioned the study of human exposures to atmospheric concentrations of selected chemicals that is reported here.

The study of human exposure to certain chemicals is only one element of a health risk assessment. Health risk depends on:

> The effect on human health of exposure to a pollutant
> The patterns of pollutant concentration
> The human population exposed to the pollutant patterns.

Since this program does not address the development or use of a health effects model, it is not known what population factors (e.g., age, sex, occupation, racial background), environmental factors (e.g., climate, diet, chemical reactions), and exposure factors (e.g., duration and dosage of exposure, concentration threshold, concentration level) are important. Accordingly, the methodologies developed for use in our study are designed to accommodate the quantification of such effects.

The results of this study are expressed in terms of both the human population exposed to different concentration levels of each substance and the dosage potential (here called dosage) for the exposed population. As used in this program, exposure is the number of people whose breathing space contains the given pollutant at a specified concentration. Dosage is not the quantity absorbed by human bodies, but for this program merely the potential dosage measured by a concentration multiplied by the number of people exposed. Both exposure and dosage are presented in annual terms.

THE STRUCTURE OF THE STUDY TEAM

The study of human exposure and dosage to atmospheric concentrations of the selected chemicals involves three major aspects, which may be formulated in terms of "what, where, and who" questions:

- > What material is released to the atmosphere?
- > Where does the material go?
- > Who receives the material at the places it reaches?

Each of these three program elements was addressed by a specific study group:

- > Systems Applications, Incorporated (SAI)--SAI managed the program and developed and carried out all transport and dispersion analyses (where); defined and executed the exposure/dosage computations (who); and undertook all auxiliary studies, such as the species monographs, reactivity studies, etc.
- > Hydroscience, Incorporated (HI)--HI performed all emissions work (what), determining the locations, processes, emission characteristics, and emission rates of all sources of the studied pollutants.
- > Minimax Research Corporation (MRC)--MRC created the population data file (who) and the computer program used to interpolate population concentration data and calculate exposure-dosage.

The Principal Investigator of the program was Gerald Anderson of SAI, and the SAI program associate manager was Chung Liu. Hoi-Ying Holman (SAI) carried out the programming of the "matrix modeling." The associate manager for emissions studies was Dwight Erickson of HI, and the associate manager for exposure/dosage software was Dr. Carlos Puig of MRC.

STUDIED CHEMICALS

Early in the program study period, the EPA presented a list of 41 chemicals to be assessed in this study. Subsequently, the following six chemicals were deleted from the list under EPA instructions:

Acetylene tetrachloride
Bischloromethyl ether (BCME)
Chloromethyl methyl ether (CMME)
Methyl iodide
1-naphthylamine
2-nitropropane.

Acetylene tetrachloride and 1-naphthylamine were deleted from the list because preliminary review of available information indicated that neither chemical is any longer produced or used in the United States. CMME is an intermediate created and consumed captively in the manufacture of ion exchange resins. BCME is an impurity also created with CMME. Available information indicated that BCME and CMME are totally consumed when the reaction to form ion exchange resin is completed. The only potential emissions source of either of these chemicals is through an emergency vent of the reactor at some time when one or both of the chemicals is present. Methyl iodide is an extremely small-volume specialty chemical with an estimated annual production of 50,000 pounds. Emissions from production and use as a reagent would be negligible. The IMC Corporation plant, located at Sterlington, Lousiana, is the only chemical plant that produces 2-nitropropane. This chemical is another small-volume specialty chemical. State air emissions files indicate that no 2-nitropropane emissions results from its production.

Table 1 is a complete list of the remaining 35 chemicals. Emissions data were estimated for all of them, with the exceptions of dimethylnitrosamine and nitrosomorpholine. These two nitroso compounds are not emitted from industrial processes but can be formed in the atmosphere as a result of reaction between nitrous acid and certain amines (Hanst et al., 1977). To estimate ambient concentrations of the nitroso compounds, emissions data for their principal amine precursors, dimethylamine and morpholine, were estimated and an estimate of atmospheric production was developed.

HEALTH RISK ANALYSIS

Human exposure analysis is only part of health risk analysis. The latter is based on the concept that adverse physiological changes may be produced in human tissue that has contacted or absorbed toxic airborne materials. The change might depend--at least statistically--on some characteristic of the individual (e.g., age, sex, occupation, racial background), on the complete time pattern of the pollutant received (amount of dosage received over exposed* time), and on any measure of that pattern. Pollutant patterns can be measured in several ways:

- Total dosage.
- Dosage in a given time.
- Exposure at or above a given dose rate.
- Linear or nonlinear and continuous or noncontinuous functions of any of the above measures.

---

* Exposure is the occurrence of contact between human and pollutants. Dose is the total amount of material received. In this report, the concentration to which a person is exposed on an average annual basis is a measure of the potential dose he may receive. This quantity, summed over all exposed persons, is referred to here as dosage.

TABLE 1. LIST OF CHEMICALS FOR HUMAN EXPOSURE/DOSAGE ESTIMATION

No.	Chemical
1	Acetaldehyde
2	Acrolein
3	Allyl chloride
4	Benzyl chloride
5	Beryllium
6	Carbon tetrachloride
7	Chlorobenzene (mono)
8	Chloroform
9	Chloroprene
10	m-Cresol
11	o-Cresol
12	p-Cresol
13	o-Dichlorobenzene
14	p-Dichlorobenzene
15	Dimethylnitrosamine
16	2,3,7,8-TCDD (dioxin)
17	Epichlorohydrin
18	Ethylene oxide
19	Formaldehyde
20	Hexachlorocyclopentadiene
21	Manganese
22	Methylene chloride
23	Nitrosomorpholine
24	Nickel
25	Nitrobenzene
26	PCBs
27	Phenol
28	Phosgene
29	Propylene oxide
30	Toluene
31	1,1,1-Trichloroethane
32	Trichloroethylene
33	m-Xylene
34	o-Xylene
35	p-Xylene

Determining the health risk to a person requires knowledge of the coefficients of dependence on factors such as those listed above. Providing the inputs required for a health risk analysis, then, must include identification of the following:

> A health effect as a function of characteristics of the exposed person and of a pattern of exposure to an airborne chemical.
> Emissions sources and emissions rates of the chemical.
> The dispersive environment of the source.
> The chemical and physical properties of the chemical in the ambient air.
> The population distribution patterns, stratified by identifying characteristics, that are subject to the influence of the sources.

Three general tasks are required to convert these inputs to a health risk assessment:

> Estimation of concentration patterns of the pollutant in time and space.
> Computation of the appropriate measure of the concentration patterns.
> Summation of the product of the concentration pattern measure, the health effect coefficients, and the population in each class over space and time.

The limitation of the focus of this study to human exposure rather than health risk eliminates the necessity of having to identify a health effect function. However, appropriate methods of exposure analysis depend on the form of the health effect function. The function must be presumed to depend on some function of the time history of concentration to which a person is exposed. Even statistical bases for identifying health effects functions are usually weak; therefore, the health effect functions used in practice typically are based on the simplest possible measures of a concentration pattern. The two simplest measures are exposure and dosage.

Exposure is generally related to a given concentration level. This type of model is applicable to reversible health effects. That is, below the "standard" concentration, the body can repair damage rapidly enough to suppress symptoms. As the standard is exceeded, the human body becomes less capable of repairing damage at a satisfactory rate. Thus, damage symptoms appear in more and more people. All of the so-called criteria pollutants subject to National Ambient Air Quality Standards (NAAQS) are presumed to produce reversible effects at NAAQS levels. The NAAQS themselves are exposure types of standards. Of course, sufficiently high exposure to such pollutants can produce irreversible organ damage or death.

Some pollutants can produce irreversible cell or genetic damage or irreversible cancerous consequences at very low concentrations. Because of the irreversibility of such effects, the total damage to the body can depend on the accumulation of such events and thus on the pollutant dosage that the body receives. If such damage is sustained at very low levels, it may well be generally undetectable, yet its cumulative or randomly critical nature may create an unacceptable health risk to the total population. Some bodily damage may be reversible or inconsequential at low levels of exposure or dosage but irreversible at higher levels. Such behavior is referred to as "threshold" variation.

It is presumed that the effect of carcinogenic materials is to produce critical cell damage. Thus, carcinogenic health effects models generally are dose (i.e., integrated exposure) models, not exposure models. The lack of firm statistical bases often leads to the adoption of nonthreshold, linear models, even though thresholds and nonlinear effects might be expected.

If linear (dose) models without thresholds are to be used for carcinogen (or other) risk assessment, estimation of exposure at specified levels becomes irrelevant or, at least, nonintuitive. For example, a carcinogen risk analysis may be based on a linear, nonthreshold health effects model. The total health risk would thus be proportional to the long-term exposure summed for all affected people for the identified period. Exposure of many people at low concentrations would be equivalent to exposure of a few to high concentrations. The atmospheric dispersion that reduces concentrations would also lead to exposure of more people; therefore, increments to population risk would not necessarily diminish with increasing dispersion time or distance. Limits to human risk would exist only if the concentration or population patterns were bounded. Since the model does not exclude background concentrations from global transport, bounding of the concentration patterns by either chemical decay or scavenging by such phenomena as precipitation and respiration would be necessary for legitimate analysis by a linear, nonthreshold model. However, arbitrary boundary limits (e.g., 20 km for specific point sources) were set for this purpose.

In spite of this argument, a linear health effects model was assumed in this study. It is not practical to determine the time history of exposure for a single person or for all the population as a whole in this study, so the annual average exposure levels were estimated. Population exposure was defined in this study as the number of people exposed to annual average concentrations of ambient chemical no less than certain exposure levels. Dosage was defined as the product of population and concentration (at no less than certain levels) to which they would be exposed. Therefore, both exposure and dosage are functions of exposure level.

A time factor has been built into both exposure and dosage. The health risk is proportional to the long-term exposed concentration under the linear assumption; therefore the model predicts long-term (annual) ambient air concentrations at locales where people live.

SOURCES AND EMISSIONS

The list of chemicals presented in Table 1 contains materials of quite disparate character. Distinctive characteristics include the following:

> Phase--Solids, liquids, and gases (at ambient conditions) are represented.

> Chemical Reactivity--Some are nonreactive; some decay by atmospheric chemical processes; and some are created by such processes.

> Ubiquity--Some are widely distributed; others are found in isolated locations, isolated times, or both.

> Mode of emission--In general, when a pollutant is exposed to the atmosphere some fraction is lost to the atmosphere. Since each material is handled differently, it enters the air by a different mode. Some identified modes are
>
> - Evaporation from open surface.
> - Emission through a stack.
> - Emission through a vent (a vent is not designed to elevate the emitted material; a stack is).
> - Leaks in plumbing or storage containers.
> - Wind-blown dust.

> Emission rate--Rates range from minute to massive.

> Proximity to people--Materials are emitted from sites of varying remoteness.

Because of the number of characteristics that must be addressed, three different methods were used for estimating concentration patterns, one method for each of three categories of sources. The three source categories are

> Major, specific point sources--These consist of individually identified sources, usually a manufacturing plant. Such sources have known locations and modes and rates of emission. Each accounts for a significant fraction of the national emissions of some species.

> Other point sources--Sources that are too numerous, small, or of uncertain location, and yet produce isolated patterns of significant concentration, are not treated specifically. Rather, a prototype of such sources is defined, and the results of prototype analysis are multiplied by estimated numbers of sources that the prototype represents. Degreasers are an example of sources that were treated by prototype.

> Area Source--Sources that are so numerous and emit so little that patterns of concentration are analyzed only "en masse." Such sources include both stationary (e.g., home chimneys) and mobile (e.g., automobiles) types. Emission rates per unit area are estimated; emission modes are not addressed.

Emission rates, modes, locations, and times were described for each species studied. The emission work was done by Hydroscience, Incorporated (HI), of Knoxville, Tennessee. Emissions characterization involved review of trade literature, files of the various states, EPA reports and data, and site visits and correspondence with staff of specific sources.

The results of this program include the completion of emissions summaries that identify source locations and estimate the total nationwide emissions of the 35 chemicals. These summaries are included in the attached species reports. Further description of the emission estimation process is given in Section 2. Rankings of the studied chemicals by emission rate are presented in Table 2, page 20.

DISPERSION MODELING

The estimation of human exposure/dosage to atmospheric concentrations of the studied chemicals involved three computational tasks:

> Estimation of annual average concentration patterns of each chemical on the region about each source.
> Estimation of the population pattern over the area of each computed concentration pattern.
> Computation of sums of products of the concentration and population patterns to provide exposure/dosage estimates.

Concentration Patterns

The large number of chemicals and sources that were modeled in this program would consume large computer resources if conventional modeling systems had been used. To keep computer costs within reasonable bounds while ensuring that the computing effort would meet program needs, we developed a combined "reactive prototype" and "matrix" modeling system.

The estimation of concentration patterns was done with a different approach for each of the three source types described above.

> Specific point sources
> Prototype point sources
> Area sources.

Each of these types of sources requires a different modeling approach. In addition, the concentrations of some of the selected chemicals depend on reactions in large-scale plumes of photoreactive materials from urban regions or industrial complexes. Although SAI has developed and used many types of photochemical simulation models, application of such models to the number and variety of sources studied in the present program would require large labor and funding resources; hence, these models were not recommended for this program.

MAJOR (SPECIFIC) POINT SOURCES

Major sources of most of the selected chemicals are specifically identified chemical manufacturing plants. Concentration patterns due to unit emissions from such sources depend most strongly on several factors:

- Source elevation above terrain
- Wind vectors (speed and direction)
- Dispersive effects (intensity of atmospheric turbulence).

Long-term average concentrations depend on the time histories of the meteorological parameters. A useful simplification that greatly reduces computational requirements is the computation of long-term average concentrations by taking climatological weighted sums of concentrations computed for a set of discrete states of the atmosphere. This approach is used in the EPA's climatological dispersion models, AQDM and CDM; for each state of the atmosphere, these models compute Gaussian dispersion patterns. The annual average concentration pattern is then computed as a weighted summation of the patterns for each atmospheric state. AQDM and CDM are designed for application to urban regional problems with large inventories of sources. The EPA's point source models, PTMAX, PTDIS, PTMTP, and CRS, also use a Gaussian kernel, but are designed for estimating short-term (one-hour to one-day) average concentrations. The approach used to develop long-term average concentrations in the EPA's benzene exposure study (Mara and Lee, 1978) was to compute one-hour results and to infer annual averages by using assumed time-averaging period scaling factors.

In the present study, the computations were carried out taking into account the following source-specific factors:

> Climatological data from nearest or otherwise most appropriate recording station.
> Individual treatment of releases from each identified process or vent within a plant.
> Release height, speed, and buoyancy.
> Effects of wakes from nearby structures.
> Diurnal variations of emissions.
> Seasonal variations of emissions.
> Urban or rural character of area.
> Atmospheric chemical reaction after release of emissions.

GENERAL POINT SOURCES REPRESENTED BY PROTOTYPE

Some point sources are not treated individually because of their number and emissions strength; such sources are too numerous, their emissions are too small to warrant individual modeling, or both. Unlike area sources, these sources are separated widely enough that their patterns of pollution impact do not generally overlap. In lieu of the individual modeling of each such source, a prototype source is defined to represent each such source; dispersion and exposure/dosage patterns are computed for the prototype; and results are multiplied by the number of sources the prototype represents.

Such sources were modeled using the matrix model for unit emissions rates rather than emissions rates for actual, specifically identified sources. When appropriate, prototype sources were analyzed for each region of the country using meteorological data representative of that region. The nine geographic regions in the United States (see Figure 1) are used here, and a model source would be defined for each generic source category in each of the nine regions.

AREA SOURCES

Area sources of either a selected chemical or a precursor present a common problem for modeling. In particular, the rich and complex patterns of hydrocarbon emissions from general urban and industrial sources either include or might produce through atmospheric photochemical reactions some of the species on the analysis list. The treatment of such species in photochemical airshed modeling is difficult (Anderson et al., 1977; Tesche and Burton, 1978). The effort required for any one such exercise is substantial, and the effort required for a comprehensive analysis of all urban regions relevant to this program would be prohibitive.

We have treated reactive effects through judicious scaling of nonreactive results by factors developed by photochemical "prototype" definitions. Nonreactive modeling of area sources was carried out by use of a box model (Hanna, 1973). This type of model can be used to treat general, undifferentiated source densities in an urban region. Box model results for each wind speed and stability, weighted by climatological probabilities, were used to compute long-term averages.

Basic box models cannot portray effects of nonuniform source patterns. If, for particular chemical species or particular source classes, the dependence of emissions on population density or other identifiable parameters is apparent and significant, we have used modifications to the box model approach. As an example, it might be assumed in modeling products of combustion of the lighter fuel oil distillates that source distribution patterns are proportional to population density patterns, because most of such fuel is burned in residential furnaces in cold-weather cities.

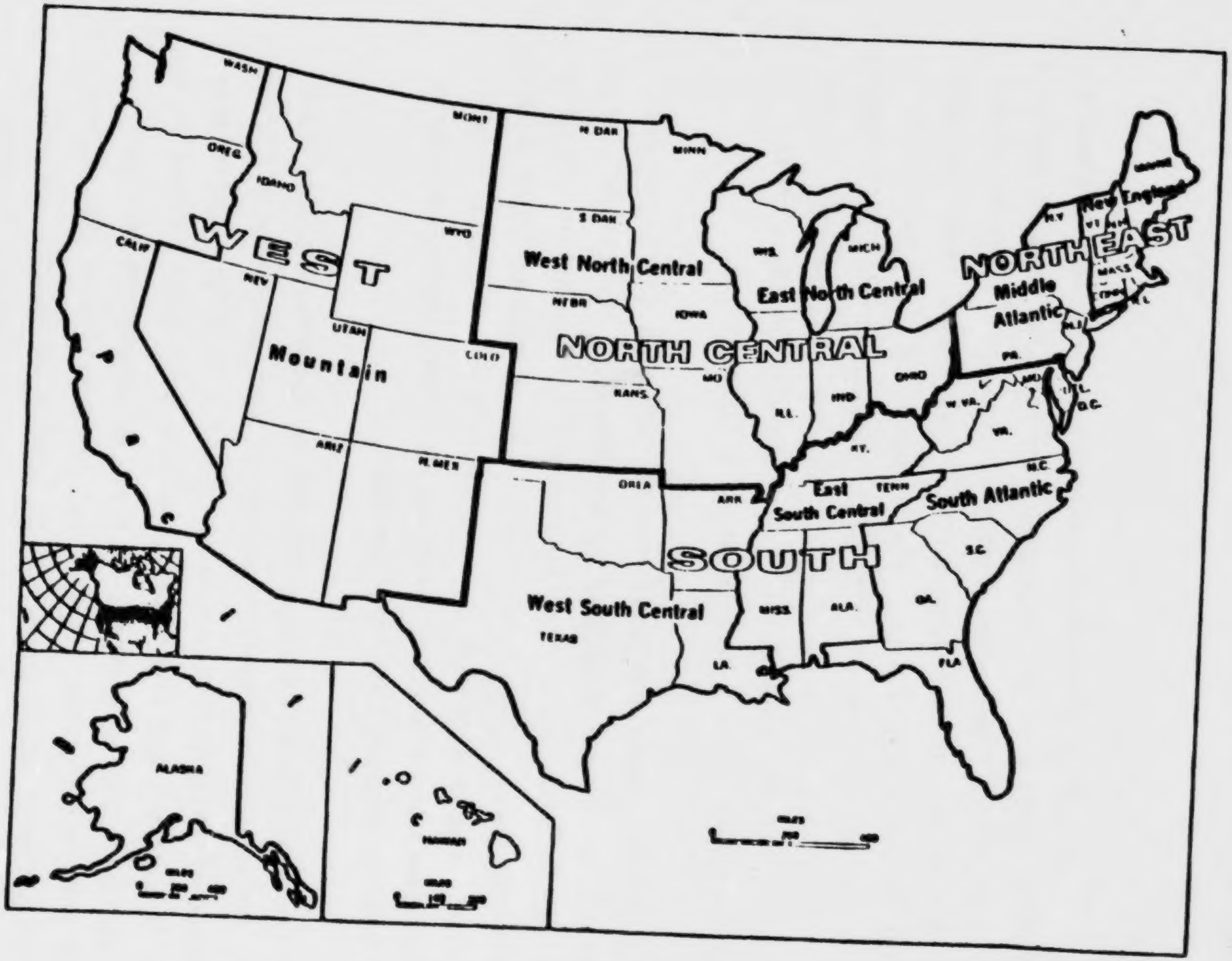

WEST
Mountain
NORTH CENTRAL
West North Central
East North Central
NORTHEAST
New England
Middle Atlantic
SOUTH
South Atlantic
East South Central
West South Central
WASH
OREG
CALIF
IDAHO
NEV
MONT
WYO
UTAH
COLO
ARIZ
N. MEX
N DAK
S DAK
NEBR
KANS
MINN
IOWA
MO
WIS
MICH
ILL
IND
OHIO
KY
TENN
N.Y.
VT
MASS
PA.
N.J.
MD
DEL
D.C.
W VA
VA.
N.C.
S.C.
GA.
FLA
ALA.
MISS
LA.
ARK
OKLA
TEXAS
ALASKA
HAWAII

FIGURE 1. U.S. GEOGRAPHIC REGIONS

Where possible, we have addressed dispersion modeling requirements by using models that

> Are specific to source type
> Are specific to site
> Address relevant physical and chemical phenomena
> Address relevant time and space scales
> Are based on EPA-recommended algorithms
> Are computationally efficient.

More extensive descriptions of the dispersion modeling methods used are presented in Section 3.

POPULATION MODELING

Population modeling is based only on where people live. It was also done using different methods for each of the three types of sources:

> Major, specific point sources
> Prototype point sources
> Area sources.

For major point sources, site-specific population patterns were extracted from U.S. Census Bureau files using data at the Enumeration District/Block Group (ED/BG) level. These data provide the finest resolution of population patterns available. The data were scaled from 1970 to a base year of 1978. Interpolations of population and concentration patterns were used to develop patterns of exposure/dosage that were then summed to produce source-specific exposure/dosage totals.

The same dispersion procedures were used for modeling of other point sources, but, since only prototype sources were addressed, population data were required only for prototypical conditions in each geographic region. Prototypical population was represented by the average population density in the urbanized areas of each region.

For area sources, only city-average population density and area were used for each city so modeled.

Extensive descriptions of these techniques are presented in Section 3. Further description of the population data bases is given in Section 2.

RESULTS

Twenty-nine reports are presented as attachments to this report. Each report summarizes, for a single species, the following:

- Emissions sources, including number, identification, and location of sources of each type.
- Emission and rate modes.
- A table of physical and chemical data.
- Tables of concentration, exposure, and dosage for each source and source type, and total exposure and dosage.

The emissions study identified and provided computations of the concentration, exposure, and dosage patterns for the following:

- There were 311 major chemical manufacturing or consuming plants covered in this study. Because some major chemical plants were involved in more than one chemical, specific point source modeling was applied for 538 plants. Since there may be more than one source type in a plant, dispersion-dosage modeling was conducted for a total of 1819 individual point sources in this study.

- There were 62 source categories involved in the prototype modeling, each with nine regions. Hence, the prototype point source modeling was conducted for a total of 558 prototype sources.
- Gaussian dispersion model computations were made for all "Urbanized Areas" (248) for each of the 77 area source categories, for a total of 19,096 runs.
- Gaussian dispersion model computations were made for all other cities (243) with a population over 25,000 for each of the 77 area source categories, for a total of 18,711 runs.
- Box model computations were made for 150 cities with populations between 2,500 and 25,000 for each of the 77 area source categories, for a total of 11,550 runs.

In total, emission estimates and dispersion, population, and exposure/dosage computations were made for 51,734 cases.

In Table 2 the 35 chemicals are ranked by their 1978 nationwide emissions. A complete list of specific point sources of these 35 chemicals is included in Attachment A.

Similar rankings of the 35 chemicals by their dosage potential to the national total population are presented in Table 3.

An extensive review of the uncertainties associated with these estimates is presented in Section 4.

TABLE 2. RANK ORDER LISTING OF STUDIED CHEMICALS BY TOTAL EMISSIONS

Rank	Chemical	Chemical Abstract Service Registry No.	Total Emissions* (lb/yr)
1	Toluene	108-88-3	2,235,529,416
2	1,1,1-Trichloroethane	71-55-6	537,580,000
3	m-Xylene	108-38-3	453,526,870
4	Methylene chloride	75-09-2	407,000,000
5	o-Xylene	45-47-6	268,493,301
6	Trichloroethylene	79-01-6	240,800,000
7	p-Xylene	106-42-3	239,267,107
8	Chlorobenzene	108-90-7	175,376,130
9	Carbon tetrachloride	56-23-5	64,610,000
10	p-Dichlorobenzene	95-50-1	49,900,950
11	Manganese	7439-96-5	35,982,111
12	Formaldehyde	50-00-0	30,490,000
13	Chloroform	67-66-3	24,040,000
14	Nickel	7440-02-0	22,369,060
15	o-Dichlorobenzene	95-50-1	12,646,624
16	Nitrobenzene	98-95-2	13,040,000
17	m-Cresol	108-39-4	10,959,325
18	Morpholine+	110-91-8	10,028,000
19	p-Cresol	106-44-5	9,124,945
20	Phenol	108-95-2	6,124,480
21	o-Cresol	95-48-7	4,504,150
22	Acetaldehyde	75-07-0	3,921,260
23	Chloroprene	126-99-8	3,523,090
24	Ethylene oxide	75-21-8	1,687,900
25	Propylene oxide	75-56-9	1,337,949
26	Allyl chloride	107-05-1	1,112,000
27	Epichlorohydrin	106-89-8	479,000
28	Beryllium	744-04-17	357,035
29	Dimethylamine§	124-40-3	215,400
30	Phosgene	75-44-5	199,438
31	Acrolein	107-02-8	97,455
32	Benzyl chloride	100-44-7	100,271
33	Hexachlorocyclopentadiene	77-47-4	59,500
34	PCBs	11097-69-1 11096-82-5	30,020
35	2,3,7,8 TCDD-(dioxin)	1746-01-6	84

---

* Actual emissions estimated as of 1978. See attached species reports.

+ Emitted precursor to atmospheric formation of nitrosomorpholine.

§ Emitted precursor to atmospheric formation of dimethylnitrosoamine.

Source: Species emissions summaries by Hydroscience, Incorporated, Knoxville, Tennessee included in attached species reports.

TABLE 3. STUDIED CHEMICALS RANKED BY ESTIMATED TOTAL U.S. DOSAGE*

Ranking	Chemical	Total Dosage [(ug/m^3) persons]
1	Toluene	1,790,880,000
2	1,1,1-Trichloroethane	477,120,000
3	Methylene Chloride	401,550,000
4	m-Xylene	348,800,000
5	o-Xylene	218,050,000
6	p-Xylene	176,200,000
7	Trichloroethylene	165,760,000
8	Chlorobenzene (mono)	141,287,100
9	Carbon tetrachloride	64,460,000
10	p-Dichlorobenzene	51,410,000
11	Manganese	34,320,000
12	Chloroform	24,240,000
13	Formaldehyde	18,768,000
14	Nickel	16,910,000
15	m-Cresol	14,030,000
16	p-Cresol	11,630,000
17	o-Dichlorobenzene	6,450,000
18	o-Cresol	5,820,000
19	Phenol	1,768,000
20	Nitrobenzene	1,114,000
21	Acetaldehyde	691,000
22	Propyleneoxide	564,000
23	Chloroprene	272,000
24	Beryllium	204,000
25	Epichlorohydrin	155,000
26	Allyl Chloride	86,700
27	2,3,7,8-TCDD (Dioxin)	75,000
28	Ethylene oxide	65,800
29	Benzyl Chloride	41,000
30	Phosgene	19,500
31	Hexachloropentadiene	16,700
32	Acrolein	15,400
33	PCBs	12,400
34	Nitrosomorpholine	6,900
35	Dimethylnitrosamine	620

---

* Potential dosage: Exposed persons times annual average atmospheric concentration to which they are exposed.

Source: Systems Applications, Incorporated, computations.

CAVEATS

The program team has sought to produce results that are as broad and flexible in scope and as rigorous and detailed as possible given constraints such as those identified below.

> Dispersed sources such as vehicle emissions and small industrial and commercial users have been linked to population, heating (degree-days) or other surrogates wherever possible. Thus, only coefficients of emissions per unit surrogate as a function of time (where appropriate) were developed for this source class.

> Site-specific exposure and dosage calculations were terminated at 20 kilometers. To avoid double counting of exposures at low concentrations, generic source exposure tabulations were terminated at distances corresponding to estimated typical source separations (dosages were not so terminated).

> Reactive production or decay rates of studied chemicals were developed only for prototype species. Reactive effects for each species were estimated using rates related to rates for the most appropriate reactive prototypical species. No attempt was made to model chemical reactions downwind of each source, and reactive effects were addressed by assuming constant rates.

- Diurnal shifts of population from residential to employment areas were not computed. Nationally comprehensive, disaggregated employment data are not available for this purpose. The methodology developed would, however, provide for this computation when specific site applications in future programs warrant assembly of a data base.
- Certain existing data that would support more detailed city specific fuel usage estimates were not collected because of resource limitations. For example, it is known that distillate fuel usage for space heating is not distributed solely by heating degree-day patterns; such use also depends on patterns of availability of alternative fuels or on the local cost of electricity, or both.
- Diurnal emissions patterns were not estimated. This is valid for continuously operated industrial sources, but it is not valid for most area or generic point sources or some specific point sources. For example, it is clear that some gas stations, dry cleaners, and businesses using degreasers close at night.
- Because diurnal emissions patterns were seldom estimated, correlations between meteorology and emissions parameters were not addressed. That is, night shutdowns were not correlated with slow, stable winds, nor with possibly preferred directions.
- The issue of the effect of world-wide exposures at vanishingly small concentrations was not addressed in the analysis (this issue is discussed, however, in Section 3).
- The issue of preferred spatial distributions of area or generic point sources was not resolved (e.g., four gas stations at a single intersection is a common deviation from a uniform density of stations).
- The atmospheric production of some species studied (e.g., formaldehyde) from other anthropogenic precursors (e.g.,

gasoline fumes) was not addressed. Such a study would require photochemical modeling of the entire country. The capability of modeling individual hydrocarbon species on such a scale is not now available.

- Natural sources of the selected species (e.g., the metals) were not considered.
- Computation of pollutant dispersion by building wakes does not address details of building shape.

RECOMMENDATIONS

We recommend that several features of the analysis and of the computer programs be addressed or improved in the course of their future use. Specifically, we recommend the following:

- Certain options (e.g., urban/rural choice of dispersion parameters) were suppressed in the final computer programs because implementing data were not available. We recommend some additional programming to permit more flexibility in the use of program options.
- An effort be made to determine and address space heating fuel use patterns.
- Available data on background concentrations of species of interest be reviewed for possible consideration in validating or supplementing dispersion studies, or both.
- Atmospheric production and associated ambient concentration estimates be made for species for which this is important.
- We recommend that detailed dispersion-exposure estimation modeling techniques be developed and applied for a small set of chemical-emitting specific sources. This would incorporate detailed plant emission characteristics, a complete decay/removal package, and population exposure characteristics.

> We recommend that a detailed urban areawide concentration-dosage modeling approach be developed. A typical metropolitan area may be selected as an example to determine the concentration-dosage patterns for certain chemicals of concern.

> We recommend that population distribution patterns and diurnal variations be examined for urbanized areas. This is of prime importance to the estimation of exposure--dosage of chemicals emitted from area sources.

> We recommend that the method of estimating the exposure-dosage be related to the current methods of estimating health effects of chemical exposure; that is, the implication of any choice of health effects model should be explicitly recognized in carrying out exposure/dosage estimations. This should provide basic information for focusing the modeling efforts on the critical threshold levels and time and dosage patterns of chemical exposure.

SECTION 2

DATA BASES

Four major types of data are essential for assessing exposures to and dosages of atmospheric chemicals:

> Emissions inventories of chemicals
> Atmospheric reactivities of chemicals
> Meteorological data
> Population distributions.

The acquisition, processing, and preparation of these data bases are delineated in this section.

EMISSIONS DATA

The development of emissions inventories for the 35 chemicals was conducted by Hydroscience, Incorporated (HI), under subcontract to SAI. HI has an extensive background in determining emission levels and controlling the release of pollutants from various manufacturing processes. HI is the prime contractor to the Emission Standards and Engineering Division (ESED), Office of Air Quality Planning and Standards, Environmental Protection Agency, for the project entitled Emissions Control Options for the Synthetic Organic Chemicals Manufacturing Industry, Contract No. 68-02-2577. The term of the contract is March 1977 to March 1980. The current estimated total cost is approximately $2.9 million. The primary objective is to gather sufficient information to allow ESED to fulfill its responsibility to establish new source performance standards and associated guideline documents for the synthetic organic chemical manufacturing industry. HI acquired the data necessary to identify emissions of chemicals that would provide a basis for dispersion model studies for human exposure assessment. Emissions were identified for each chemical for both production sites and user locations, and emissions characteristics such as quantity, rate, composition, and stack parameters were defined.

It was apparent that individual chemical emissions assessments could best be completed in a combined summary, especially in cases of common producer and user locations or where products are co-produced at the same location. Chemicals such as o-, m-, and p-cresols were summarized in one report. A total of 25 emissions summaries that cover the 35 chemicals were completed. All 25 summaries are included in Attachment A. The methodology used to identify chemical emissions is discussed here together with summarized emissions results and uncertainties involved in developing the emissions inventories.

Source Identification

In this study we identified three distinct categories of sources; each source category presents different data-gathering problems.

Specific Point Sources--

Specific point sources are defined as known locations identifiable by geographic coordinates for which the emissions of a specific chemical can be estimated and assigned. Specific point source locations were determined from a variety of published sources:

> 1978 Directory of Chemical Producers and Chemical Economics Handbook, published by Stanford Research Institute.

> "Chemical Marketing Reporter."

> U.S. Government publications, such as the U.S. Tariff Commission's "1977 Synthetic Organic Chemical Production and Sales."

> Reference guides, such as the "1977 Kline Guide to the Chemical Industry."

> Other sources, such as trade associations, trade journals and periodicals, and technical journals and periodicals.

Once the point source locations (including company name, city, and state) were determined, geographic coordinates were assigned. Most of the geographic coordinate information was obtained via personal communication with various state air agencies or, in some cases, from EPA regional offices. Information also was obtained from emissions inventory files; in some cases, HI determined coordinates by using United States Geological Survey maps. Some of the geographic coordinates obtained were in Universal Transverse Mercator units (UTMs), which were converted by use of a computer program to geodetic coordinates (latitude/longitude) by SAI.

After the locations were identified, the total quantity of the specific chemical produced or used at each of the sites was estimated. Total chemical production and use quantities were obtained from published sources. Three methods were used to determine individual site production and use quantities. When possible, total capacity and individual plant capacity figures were obtained. Total production and industry use was then distributed over each site based on the ratio of the site capacity to the total industry capacity. This was done because the total industry capacity is a much more accurate estimate than is the individual site capacity. In a second method, used in a few cases, average site capacities were estimated because only ranges of site capacities were known. In such cases, production and use quantities were then distributed by ratioing the average site capacity to the total industry capacity. Using the third method in cases for which individual site capacity figures were not available, the total quantity of production or use was distributed evenly over all sites in the industry or apportioned on the basis of number of employees at each site.

Prototype Point Sources--

Prototypes were defined and analyzed for some point sources because the sources are too numerous or unknown to allow identification of specific locations with geographic coordinates. Prototype model sources were defined for different regions and were modeled in the same fashion as specific point sources. The results were then scaled to represent all sources of the same nature. Examples of this type of source are power plants, refineries, and gas stations. Prototype point sources were used to analyze some specific chemical uses and most incidental sources of the chemicals assessed in this program.

To enable a regional analysis of exposure from sources analyzed by prototype, the prototype model source had to be defined and the number of sources in each of the geographic regions had to be determined. Total usage was then distributed over each of the regions by assuming an average quantity per site or by apportioning the use based on the number of employees in each region involved in the use of that specific chemical. Incidental source locations were distributed in the same manner.

Area Sources--

Area sources are those sources of chemical use or incidental emissions that could not be described as either a specific point source or as a generic point source because the use is too widespread or unknown. Such sources included home, business, and transportation uses of specific chemicals such as p-dichlorobenzene for moth control or toluene as a solvent in paints or as a constituent of gasoline.

Emission Estimations

Emissions Factors--

Emissions factors were developed to estimate the emissions from the production, consumption, and incidental formation of the various chemicals assessed. The emissions factor is expressed as the total pounds of a specific chemical lost to the atmosphere per pound of the chemical produced or used. Multiplication of the emissions factor by the quantity of the chemical produced or used at an individual site or in a specific geographic region during a specific time period yields the estimated chemical emissions, in pounds, for that location.

The total emissions resulting from the production or chemical intermediate use of a specific chemical are a summation of process, storage, and fugitive emissions losses:

- Process emissions are discrete losses that occur at process vents from reactors, columns, and other types of plant equipment.
- Storage emissions include losses from the raw material feed, in-process and final product storage tanks, as well as from loading and handling losses.
- Fugitive emissions are losses that result from plant equipment leaks, visual openings, evaporation from waste products, and other nondiscrete sources.

For most chemicals emitted from chemical production and intermediate consumption facilities, emissions factors were estimated spearately for process vent, storage emissions, and fugitive emissions. However, in some cases, only a total emissions factor could be determined, and further breakdown was not possible given the lack of emissions data at those specific sites.

Emission factors were not used to determine losses of chemicals used in solvent applications. Emissions resulting from solvent applications were estimated by assuming that all the solvent used, or all but a small waste fraction of the solvent used, is eventually released to the atmosphere. For the purpose of this report, emissions from the export of specific chemicals were assumed to be negligible. To develop specific chemical emissions factors, data from four different types of information sources were used:

> Level A--Plant Site Visits: These data were obtained by Hydroscience while performing tasks for EPA contract No. 68-02-2577, "Emission Control Options for the Synthetic Organic Chemical Manufacturing Industry." Under this contract HI assessed approximately for uncontrolled, controlled, and best estimates of current volatile organic compound (VOC) emissions resulting from chemical production facilities. Data were obtained by actual site visits to selected producers. Emissions estimates were developed for model plants based on the data obtained by visiting two or more producers of each chemical assessed. The emissions factors derived from this information reflect some degree of control and include only the estimated losses of the specific chemical in question. Other associated VOC losses were not included in the emissions summaries. This level of information was considered the best because it includes the most recent data available, and it incorporates some level of existing control in the emissions estimates.
>
> Level B - State Air Emission Inventory Questionnaires (EIQs): The air EIQs for most manufacturing sites are on file at various state air agencies throughout the United States. Hydroscience has obtained air files from Texas, Louisiana, Illinois, New Jersey, and others states, on

approximately 200 chemical and petrochemical manufacturing sites. These files were used to develop emissions factors for a number of the chemical-emitting processes. Emissions data on most of the questionnaires include total quantities per year of various kinds of VOC emissions from process and storage vents as well as fugitive estimates. The total emissions of a specific chemical were tabulated from process, storage, and fugitive sources for one or more producers and divided by the total production expressed as a percentage of a plant's rated capacity. The quality of the emissions data usually varies considerably. Process vent data are usually obtained from test results, while storage tank losses are usually based on AP-42 calculations. Fugitive estimates, if made, are normally obtained by the material balance method. As in the case of Level A data, only the emissions of the specific chemical in question were estimated. Other associated VOC emissions were not included in the emissions estimates.

> Level C--Other Published Sources: These emissions factors were obtained from a variety of published reports prepared by other contractors for the EPA. In the individual chemical summaries, the specific emissions factor obtained from these sources is referenced: In most cases, the accuracy of these data is not known, since the specific information used to derive the emissions factors is not given. This level of information was used only if Level A or B data were not available.

> Level D--Hydroscience Engineering Estimates: In some cases, emissions factors were not available from any of the three source levels previously discussed. Rather than omit these sources of emissions entirely, emissions estimates were made by HI process engineers. These estimates

were made using synergism between the unknown process and a process that had been previously defined. In other instances, an emissions factor for an unknown chemical intermediate use of a specific chemical was calculated based on a weighted average factor of all the other known chemical intermediate uses of the same chemical. Although specific quantification of the data quality is unknown, this is obviously the least accurate source of the four levels used.

Vent Parameter Data--

Vent parameter data are necessary for dispersion modeling of the chemical emssions. The vent parameter data in each of the chemical summaries include the number of process and storage tank vents, vent height, vent diameter, gas discharge temperature, gas emission velocity, fugitive discharge area, and building cross-sectional area. These data were obtained from the same four source levels discussed above, under emissions factors. Some data were supplied by producers during site visits, some data were obtained from EIQs, and some from other published reports or text books. The vent parameter data in the individual chemical summaries are usually an average of two or more sources of information. In cases where no data were available, they were estimated by Hydroscience engineers.

Summary and Conclusions

Emissions summaries covering 35 selected chemical compounds were completed for this program. The amount of effort required to complete each summary varied greatly. Chemicals that are produced and captively consumed, such as chloroprene, required minimal effort; chemicals with multiple production processes and multiple, complex uses and incidental sources, such as toluene, required considerably more.

The completed summaries and resulting emissions estimates are felt to be representative of current manufacturing activities for the production and use of each of the assessed chemicals. It is acknowledged that there are discrepancies between some of these estimates and others previously completed. The following points need to be considered when comparing these estimates:

- The base year for all chemicals assessed in this program is 1978. A number of the chemicals assigned for study have known toxicity problems, and considerable pressure has been exerted to restrict their use in numerous applications. As a result, almost half of the chemicals assessed had lower production totals in 1978 than in previous years. In addition, most solvent applications, which are usually the single largest source of emissions for most chemicals, have negative growth forecasts because increased concern for health and safety have brought about further use restrictions. Reduced production levels will result in reduced emissions, assuming the percent lost remains constant. Reduced solvent usage will markedly reduce total nationwide emissions of a chemical.
- The emissions factors used to estimate emissions represent only the fraction of the specific chemical that is lost. They do not take into account other associated volatile organic compounds (VOC) that normally are emitted along with the chemical being assessed. For example, nitrobenzene accounts for less than 20 percent of the total VOC emitted from nitrobenzene manufacture and captive use to produce aniline.
- Some degree of control is inherent in most of the data used to compute emissions factors. The factors do not represent completely uncontrolled emissions losses. As more old plants are taken out of service and replaced by

new ones with a greater number of more efficient control devices, the overall emissions factors will be reduced. This might result in smaller total industry emissions even if production were to increase significantly.

METEOROLOGICAL DATA

The dispersion computations carried out on this program require input data on wind speed, wind direction, and the intensity of atmospheric turbulence. The turbulence intensity was represented, as usual, by the atmospheric stability class.

Acquisition and Processing of STAR Data

Martin and Tikvart (1968) developed a computer program (the "STAR," or STability ARray program) that generated frequencies and percentage frequencies of wind direction by speed classes for each stability category from routinely collected data. The specifications of stability categories depending on wind speed and sky cover were set up by Pasquill (1961) and were modified by Turner (1964). The program was adopted for use at the National Climatic Center (NCC) in Asheville, North Carolina, where archived records of all national reporting weather stations are kept. The most up-to-date version of the STAR data from all STAR stations in the country was obtained on magnetic tape from NCC, and the matrices of STAR frequencies used in this study were taken from these tapes.

The STAR data obtained from NCC for this study were reprocessed for the following reasons:

> There are more than one set of frequency summaries for most STAR stations. By way of illustration, STAR station 14819 (Chicago/Midway) has 27 sets of data corresponding to different periods of record and different methods of

categorizing stability (e.g., one method distinguishes between day and night hours; another does not). It would be time-consuming to select the appropriate set of data for use each time a source is studied. Rather, selection should be conducted uniformly using the same criteria, and the most appropriate set of data would be used for each station.

> The entire STAR data consist of six files, and the stations are arranged in numerical order of their station codes within files 1 to 4, file 5 and file 6. Without reprocessing the data, the tape must be fully scanned for each source, the cost alone of which is sufficient incentive for data reprocessing.

> Not all data sets for all stations are in the same format or array. The great majority of data sets are developed for 16 wind directions, but there are a few with only 8. The greatest variation in the data format involves the specification of stability categories. The number of stability categories defined for different data sets varies from five to eight, and the most common variation was the inclusion/exclusion of day and night distinctions. The day-night splits were based on probabilities provided in the current STAR algorithm. The dispersion model is based on the availability of daytime and nighttime STAR data, so a day-night STAR data set was developed for each station.

The first stage in the development of an appropriate STAR data base was to manually select the most appropriate set of frequency summaries for each STAR station. The STAR Tabulations Master List (National Climatic Center, 1979) was used to make the selection by applying the following criteria, arranged here in order of importance:

> Data sets with errors or incomplete data were deleted.
> Data sets based on measurements conducted during a limited time period in a day or under special conditions would not be used.
> Data sets covering only parts of years would not be used.
> Data sets with day-night split would be selected in preference to those for which there is no day-night breakdown.
> Data sets with the longest recording period would be selected.
> Data sets with seven stability categories would be selected in preference to those with eight; sets having six and five categories would be selected last.
> Data sets with the most recent records would be selected preferentially.

The selected data sets were then reprocessed into a common format. A computer program was coded and used for selecting the appropriate data sets and converting these data sets with different specifications of stability categories into the default stability array with 16 wind directions, 6 wind speed classes and 7 stability categories (A, B, C, D_{day}, D_{night}, E, and F). Following are the basic rules used in conducting such conversions (U.S. EPA, 1977):

> Day-night data sets with seven stability categories are in the default format.
> For day-night data sets with six stability categories, a seventh category, F, would be added with all zeros for its frequencies (F frequencies having already been assigned to E).
> For day-night data sets with eight stability categories, the frequencies for the last two stability categories (F and G) would be combined into a single category (F).

- For data sets with five stability categories, the fourth category (D) would be split into two categories (D_{day} and D_{night}) with 60 percent of the frequencies assigned to D_{day} and 40 percent to D_{night}. The original fifth category would become category E, and a new category with all zero frequencies would be added as category F.
- For data sets with six stability categories, but without a D_{night} category, the fourth category would be split (60:40) into categories D_{day} and D_{night}.
- For data sets with seven stability categories, but without a D_{night} category, the fourth category would be split (60:40) into D_{day} and D_{night}, and the last two categories in the original data set would be combined to form category F in the new default format.
- For data sets with eight stability categories, but without a D_{night} category, the fourth category would be split (60:40) into D_{day} and D_{night}. The last three categories in the original data set would be combined to form category F in the new default format.

The reprocessed data sets would have a format including 16 wind directions, six wind speed classes, and seven stability categories with categories A, B, C, and D_{day} in the daytime and categories D_{night}, E, and F in the nighttime. There are data sets for 311 stations in this reprocessed STAR data file; their locations and recording periods are listed in Table 10.[*] This data file was used for dispersion modeling of chemical emissions from specific and generic point sources. It is also in a form suitable for direct application for most long-term air quality modeling.

---

[*] Because of its length, this table appears at the end of this subsection on pp. 64 ff.

STAR Station Selection

Meteorological data recorded at the STAR station nearest to the source may be used in the dispersion modeling. However, local meteorological trends and topographic features may be more important factors in selecting a STAR station than is the absolute distance between the source and the station. A STAR station with climatological conditions most similar to those of the source of emissions may not be the nearest station, so the STAR stations were manually selected to take into account these factors.

The STAR station selection process developed and used in this study consists of a crude candidate identification process and a detailed assessment process.

Preliminary Candidate STAR Station Identification Process

The purpose of the preliminary process is to identify 2 to 10 candidate STAR stations for each major point source. The major criteria used in selecting these candidates are the availability of STAR data and the absolute distance between the source of emissions and the STAR station. Only those 311 stations listed in Table 10 were considered STAR stations here. The following steps were involved in this process:

> All of the 311 STAR stations were computer-plotted on four transparency maps [(Figures 2 to 5].* The five-digit code of each STAR station was printed on the maps with the third digit representing the exact location of the station.†

---

* Because of their length, these figures appear at the end of this subsection on pp. 80 ff.

† All codes that do not overlap in printing are presented in Figure 2. Potential overlapping codes are printed on subsequent figures [3 - 5].

> Information on each specific point source of emissions was collected:
  - Company name.
  - Plant location.
  - Geodetic coordinates (longitude and latitude).

> Each of the sources was computer-plotted on a map with the same coordinates and scales. For example, six sources are plotted on the background maps of Figures 2 through 5.

> By overlapping the STAR station transparency maps and the emissions source maps, the candidate STAR stations were identified for each emissions source based on the nearness of the STAR stations to the emissions sources.

TABLE 4. EXAMPLE OF LOCATION OF CHEMICAL-EMITTING SOURCES

No.	Company	Location	Latitude	Longitude
1	Dow	Freeport, TX	28°59'30"	95°23'35"
2	Amoco	Decatur, AL	34°36'12"	86°58'24"
3	Celanese	Bishop, TX	27°34'06"	97°49'27"
4	DuPont	LaPlace, LA	30°04'00"	90°32'00"
5	Hercules	Hopewell, VA	37°15'34"	77°17'14"
6	FMC	S. Charleston, WV	38°22'10"	81°40'02"

Detailed STAR Selection Process

Of paramount importance in this process is the matching of STAR stations and emissions sources that are in similar local meteorological regimes and are influenced by similar orographic (topography on the scale of mountain ranges) conditions. Major features considered here include the following:

- > Surface thermal patterns, which can affect the local wind. For example, the local sea-land breeze wind system is usually limited to surface-based layers several hundred meters thick. This layer, of course, is where chemicals are emitted; it is important in our study, especially for chemical plants located on ocean coasts or adjacent to large lakes. Another example concerns fohn winds, the influence of which was considered for emissions sources located in Montana (Chinook) and in Los Angeles County (the Santa Ana wind). About 10 STAR stations were chosen in consideration of local winds.
- > Wind patterns are taken from the Climatic Atlas (U.S. Environmental Data Service, 1968) and from maps of the U.S. Geological Survey (1:500,000; 1:125,000). We have matched about 20 emissions source-STAR station couples for Pacific and Atlantic coasts and Great Lakes shore.
- > Topographical effects, such as that of mountain-valley wind. The behavior of the wind in ridge-valley topography depends, on one hand, on the relationships between the wind direction and the solar azimuth, and the orientation of the ridge lines and valleys on the other. These local wind effects were taken into consideration for selection processes, especially for emissions sources located in the valleys of the Cascades and coastal ranges (northwestern states) or the Appalachian Mountains (Eastern states).

- Urban effects, including wind flow disturbances by urban thermal or frictional elements such as organized patterns of urban skyscrapers (Chicago, New York City, Los Angeles metropolitan, etc.). Such features substantially influence airstream and, consequently, the diffusion of air contaminants. If an emissions source is located in a small city, and if STAR stations in a large city and in a small city are equidistant from the emissions source, then preference was given to the STAR station in the small city.

If two or more STAR stations were equally appropriate, preference was given to the station with the longest and most recent period of record; this information can be found in Table 10.[*]

Table 11 lists all the specific point sources identified in this study, together with the STAR station selected for each. The latter were selected by means of the selection process described above. Table 5 lists the location and the selected STAR stations for the 12 PCB incinerators.

Meteorological Data Base for Prototype Point Source Modeling

A prototype model source was defined to represent all the sources of the same nature in each region,[§] so it was desirable to define a set of meteorological data for dispersion modeling that is representative of the whole region. However, the use of a mean or composite matrix of climatological frequencies of occurrence in a regional model source emissions dispersion estimation would not be appropriate, because the averaging pro-

---

[*] pp. 64 ff.

[†] pp. 72 ff.

[§] See Figure 1.

TABLE 5. SELECTED STAR STATIONS FOR PCB INCINERATORS

NO.	SITE	LATITUDE	LONGITUDE	STAR STATION
1	ATLANTA, GA	33 45 17	84 22 51	13874
2	BATON ROUGE, LA	30 33 35	91 15 30	13970
3	BRIDGEPORT, NJ	39 46 0	75 22 0	13739
4	CHICAGO, IL	41 52 0	87 43 38	14819
5	DEER PARK, TX	29 45 50	95 9 0	12906
6	DENVER, CO	39 43 12	105 0 0	23062
7	EL DORADO, AR	33 14 38	92 18 45	93992
8	LOS ANGELES, CA	34 0 0	118 0 0	23174
9	RICHMOND, VA	37 28 53	77 25 6	13740
10	SANDUSKY, OH	40 26 15	82 41 21	14891
11	SAN FRANCISCO, CA	38 0 0	122 0 0	23234
12	WATERFORD, NY	42 49 3	73 45 13	14735

cess leads to loss of characteristic biases in the original records. For example, if the prevailing wind is from a different direction at each of four stations that are averaged, the mean will have a more isotropic distribution with no strongly prevailing direction. Therefore, typical climatological data recorded at STAR stations that are representative of each region were selected and used for generic source modeling; the Climatic Atlas of the United States (1968) was used as the basis for selection. The major criteria used in selecting each representative STAR station include the following:

- Representativeness of annual surface wind rose[*]
- Availability of STAR data at the station
- Size of the urban area at or near station.

Table 6 lists the code and location of the STAR station selected for each region. The meteorological data recorded at these stations were used to estimate the concentration patterns in the vicinities in generic point sources.

POPULATION DISTRIBUTION DATA BASES

The estimation of human exposure to atmospheric chemicals requires knowledge of both concentration patterns and population distributions. Errors in specifying either of these factors affect the reliability of human exposure and dosage estimates. The acquisition, validation, and processing of population data were performed by Minimax Research Corporation under subcontract to SAI. This subsection summarizes the approaches and results of these efforts in these aspects. (The User's Manual and Programmer's Manual for applying the processed population data in specific point source exposure-dosage estimation are included in Attachment B.

---

[*] Selected stations had wind roses like those of most other stations.

TABLE 6. SELECTED REGIONAL PROTOTYPE STAR STATIONS WITH REPRESENTATIVE REGIONAL CLIMATOLOGICAL CONDITIONS

Region Code	Region	STAR Station				
		Code	Site	Location	Longitude	Latitude
1	New England	14739	Boston	Boston/Logan	71°02'	42°22'
2	Middle Atlantic	94789	New York	New York/J.F. Kennedy	73°47'	40°39'
3	East North Central	14855	Chicago	Glenview	87°50'	42°05'
4	West North Central	14942	Omaha	Omaha	95°54'	41°18'
5	South Atlantic	13874	Atlanta	Atlanta	86°26'	33°39'
6	East South Central	13882	Chattanooga	Chattanooga/Lovell	85°12'	35°02'
7	West South Central	12923	Houston	Galveston/Scholes	96°52'	29°16'
8	Mountain	23062	Denver	Denver/Stapleton	104°52'	39°45'
9	Pacific Coast	23174	Los Angeles	Los Angeles	118°24'	33°56'

Population Data Acquisition

The Computer Science and Applied Mathematics Division of the Lawrence Berkeley Laboratory (LBL) has assembled an extensive collection of computerized data bases from federal government agencies and contractors. Several of these data bases that could be used in assembling a population distribution data base were reviewed.

The LBL data bases are organized according to the system used by the U.S. Bureau of the Census. Statistics are reported at various levels: state, county, Standard Metropolitan Statistical Area (SMSA), census tract (CT), enumeration district (ED), or block group (BG), and so on. The SMSAs are composed of one or more contiguous counties (or, in New England, cities and towns). Counties within SMSAs are subdivided into census tracts (covering an average of about 6,000 people), and the tracts are subdivided into block groups (covering an average of about 800 people). With some exceptions, areas outside of SMSAs are not tracted. Non-SMSA counties were divided into enumeration districts (ED) in the United States in 1970. An ED in the non-SMSA counties would be equivalent in terms of average population to a BG in the SMSA counties.

The population distribution data bases must contain, at a minimum, the following information for each designated area (county, tract, or block group):

- The Federal Information Processing System (FIPS) code of the area.
- The 1970 census population count.
- The geodetic coordinates (latitude/longitude) of the 1970 census population centroid.

Other information would be useful, but not necessary. Such information would include, for example, area (water, land, and total) and population density.

To the fullest possible extent, the resolution of the population distributions should be commensurate with dispersion pattern resolution. The effective radius of dispersion of emissions varies considerably with source characteristics and atmospheric conditions. Some emissions are highly concentrated at certain azimuths and radii, whereas others are more uniformly distributed. Detailed population distribution statistics are required to estimate exposure to concentrated emissions. Using comparatively large areas, such as counties, as the geographic unit of enumeration could seriously bias the results in such cases. These considerations dictate the use of the finest resolution possible in compiling the population statistics. Unfortunately, however, the cost of creating, maintaining, and using a population distribution data base increases rapidly with the degree of geographic detail. Within the context of this study, cost must be balanced with level of detail. Accordingly, the current availability of population data bases at LBL was first reviewed.

County Level Population Data Bases--

A data base entitled "Geographic Area Code Index (GACI)" contains the following items for each state and county in the United States:

> FIPS code
> Name
> Geodetic coordinates of the population centroid
> Population
> Land, water, and total areas
> Population density.

This data base can be used in its present condition with only minor reformatting.

Census Tract Level Population Data Bases--

At the tract level, FIPS codes and population counts are readily available from several data bases. The most convenient source for codes and populations seems to be the "Master Enumeration District List (MEDList)." Centroids must be computed from one of two sources:

- > The raw digitized tract boundaries in the "US by SMSA Census Tract" map data base, which contains coordinates for 1.09 million boundary points for some 35,900 tracts. These data have been used many times and are quite clean.
- > The centroids of the constituent ED/BGs in the "Master Enumeration District List--Extended" (MED-X) data base.

Processing the tract map files would require the development of a moderately complex program, portions of which could be adapted from existing LBL programs. To cover an entire county, further processing would be required to merge the resulting tract level data base with portions of the county level data.

ED/BG Level Population Data Base--

The "Master Enumeration District List--Extended (MED-X)" data base contains, for each block group and enumeration district, the following variables:

- > Complete FIPS codes.
- > Population count.
- > Latitude and longitude of population centroid (areas are not available).

This data base contains approximately 350,000 records and 45 million characters. However, the data base had not been cleaned, and the known defects in MED-X included the following:

> Several hundred illegal alphabetic characters in numeric fields.

> An unknown number of erroneous centroid coordinates.

> The omission of half of the state of Louisiana and part of Vermont.

Despite these defects, MED-X contains all of the essential information required in a readily usable form. It is arranged so that populations and centroids can be easily and cheaply computed for areas larger than ED/BGs, such as tracts and counties. As a result, it provides more options in choosing the degree of resolution of the population distribution data base for different parts of the country. In addition, the MED-X base was determined to have the most accurate data for both population counts and distribution, and it offers the finest resolution.

The severity of problems with MED-X was estimated to be marginal after spot checking for illegal alphabetic characters and comparing county centroids and populations computed from MED-X with those listed in the county level base discussed above. The MED-X data base was selected for this study.

Population Data Validation

MRC undertook a thorough evaluation of both the internal consistency of MED-X and its consistency with independent external figures. At the start of the validation effort, two copies of MED-X existed at LBL; one was already in LBL-compatible format from Argonne National Laboratory (the ANL version), which was missing approximately half of Louisiana and 15 ED/BGs in Vermont; and another in IBM-compatible format from Oak Ridge National Laboratory (the ORNL version), which had never been used at LBL. The ORNL versions of Louisanna and Vermont were found to be complete and were used to replace the corresponding missing portions of the Argonne version. This revised version of MED-X was subjected to a detailed evaluation.

The MED-X validation process consisted of five separate tasks:

- Detection of missing or altered data resulting from tape errors.
- Verification of record formats (typographical errors and records out of order).
- Comparison of population sums of ED/BGs in each county to MED-X county population figures.
- Comparison of ED/BG centroid coordinates with digitized county boundaries.
- Comparison of MED-X state and county population figures with published 1970 census figures.

The first three tasks were conducted to check the internal consistency of the MED-X data base. The last two tasks were external checks performed to assess the overall accuracy of MED-X with respect to incorrect or geographically misplaced populations. Two kinds of errors cannot be detected by comparison with other independent sources, namely, misplaced ED/BGs that fall within the encompassing census areas and errors in individual ED/BG population figures.

Such errors, if reasonably infrequent, would have little effect on the final exposure results except in the rare instance that a substantial population error occurred in the immediate vicinity of an emissions source. The 20 km radius exposure area about each source covers only 0.0025 percent of the area of the contiguous U.S., and only over a small part of that area do the chemical concentrations vary widely. Therefore, such rare errors are extremely unlikely to significantly affect the exposure results.

The results of each of the five validation tasks may be summarized briefly.

Missing Records--

Besides the missing data for Louisiana and Vermont, which were replaced by the ORNL version, there was no detection of missing or altered data.

Format Consistency--

Four typographical errors were found and corrected. These errors took the form of nondigits in numeric fields. Incorrect digits undoubtedly exist, but they cannot be detected except by their effects on the population distribution. The order of records on the tape was found to be correct.

Internal Population Consistency--

Populations for 2 of the 3141 counties (Keokuk County, Iowa, and Bergen County, New Jersey) did not equal the total population of their ED/BGs. The cause of these errors has not been determined, and no correction has been made. The total of the ED/BG populations for Keokuk County fell short by 173; the total for Bergen County was 3,387 over the corresponding county figure.

ED/BG Coordinate Consistency--

A total of 12,859 (5.5 percent) of the ED/BGs in the contiguous United States, containing 5.75 percent of the population, fell outside the digitized boundaries of their corresponding counties. Table 11 classifies these ED/BGs by the distance of their centroids from the nearest point on the county boundary. Undoubtedly, other ED/BGs with incorrect coordinates fall within their boundaries; therefore, the error counts above are lower bounds. However, most of the ED/BGs that fall immediately outside (within 1 km) are attributable to either digitizing errors in the county boundaries or concavities in the ED/BG boundaries that cause the ED/BG centroid to be outside its boundary; such discrepancies are not errors. Further-

TABLE 7. DISTRIBUTION OF ENUMERATION DISTRICTS/BLOCK GROUPS (ED/BDs) HAVING POPULATION CENTROIDS LOCATED OUTSIDE THEIR CORRESPONDING COUNTIES

Distance from County Line (km)	No. of ED/BGs	Proportion of Outlying ED/BGs	Proportion of All ED/BGs
0.1	2,182	16.97%	95.37%
0.5	7,533	58.58	97.69
1.0	10,265	79.82	98.87
2.0	11,893	92.49	99.58
5.0	12,475	97.01	99.83
10.0	12,711	98.85	99.94
20.0	12,815	99.66	99.98
100.0	12,857	99.98	99.99
200.0	12,859	100.00	100.00

Source: Minimax Research Corporation consistency check of U.S Census Bureau files.

more, the county codes used in the comparison were those to which the ED/BGs belonged in 1970. Since that time, some of the county boundaries have moved and the county boundary file has been updated. Thus, some of the ED/BGs that fell more than 2 km outside their county boundaries may really be outside the current county boundaries. It is interesting that of the 922 ED/BGs that fell between 2 and 20 km outside their counties, 564 occurred in only 23 of the 188 associated counties. This concentration of discrepancies in so few counties suggests the affect of boundary changes rather than of coordinate errors.

Statistical analysis of the outliers that are almost certainly errors (those beyond, say, 5 km) may provide an estimate of the distribution of all such errors. Alternately, ED/BG coordinates could be compared to digitized census tract boundaries for SMSA counties. These additional tasks could further quantify the probable error by county, but they seem unnecessary.

County Population Consistency--

The county population figures from the MED-X county records were compared to the 1970 county populations in Table 24 of the 1970 Census of Population, United States Summary, Vol. 1, Part 1, keypunched at LBL. The discrepancies were then double-checked manually against the published document. Of the 3141 counties and county equivalents compared, 46 (1.5 percent) did not match. The net population difference for the entire country was 34,907 (0.017 percent of the 1970 U.S. population). It is very likely that the published figures, which were the first ones produced by the Bureau of the Census, are less reliable than those in MED-X.

MED-X was found to be the most accurate and the most detailed of all the population distribution data bases at LBL. The relatively few errors found in MED-X affect exposure results less than the lower resolutions of the alternatives.

Population Data Processing

MED-X contains the population centroid coordinates (latitude and longitude) and the 1970 population of each ED/BG in the country (50 states plus the District of Columbia). In addition to these essential data, MED-X contains large amounts of descriptive and summary data. While these data were invaluable in verifying the high degree of accuracy of MED-X, they interfere with efficient access to the small subset of information needed for the exposure calculations. Moreover, MED-X is collated by Federal Information Processing System (FIPS) codes, which are assigned alphabetically by state and county. These codes are not appropriate for accessing ED/BG records by their locations. The efficiency design goal required that a data base be created containing only the essential information, and that it be organized to permit access to only the relevant geographic areas. To this end, a new, smaller data base was produced from MED-X.

MED-X was reduced in two phases to a randomly-accessible binary file that contains only the data essential for exposure estimation. An indexing system was also created to locate the appropriate ED/BGs. A separate binary file of county-level growth factors, based on the 1970 to 1978 growth factor at the county level and used for scaling population figures to 1978 estimations, was also produced. The entire system, based on MED-X ED/BG population data, was used for estimating the human exposure and dosage of atmospheric chemicals resulting from specific point source emissions.

ATMOSPHERIC TRANSFORMATIONS OF TOXIC COMPOUNDS

Species monographs for the 35 toxic compounds included in this study are presented in Attachment A. It is the purpose of this section to explain the procedures used to describe the transformations in the atmosphere that are undergone by the various compounds. However, the information presented is subject the following caveats:

> First, the gas phase photochemistry of many of these compounds is not well known; in several instances, no information about the behavior of the compound in the gas phase is available. Accordingly, many of the reaction rates given are estimates, with possibly large margins of error, based on liquid phase chemistry or on the known behavior of chemically related compounds.

> Second, a compound does not necessarily become less toxic even though it undergoes transformation and decay. A good illustration of the point is acetaldehyde, which decays to form formaldehyde--another compound on the list of toxic chemicals. It may be that some of the 35 toxic compounds decay to other substances perhaps even more toxic than the precursors; current lack of knowledge regarding formation yield and toxic effects could result in such occurrences passing unnoticed.

Given the considerable body of knowledge that does exist, the procedures discussed below were used to estimate the atmospheric lifetimes of the 35 toxic compounds.

Decay

A variety of studies have reported the lifetime or atmospheric residence time of many of the listed chemicals. Too often the basis for the decay estimates is not given, so in many cases we were unable to verify prior estimates of chemical reaction rates and could not compare and reconcile the results of these past studies. In recognition of the uncertainty of reaction data, we have adopted the concept of a reference species against which to compare the relative rates of reaction for the important photochemical pathways. We also state the assumed ambient concentrations of hydroxyl radical and ozone, the principal species that attack and degrade gas phase organic compounds.

Most chemical destruction of gaseous compounds in the atmosphere occurs by one of the following three mechanisms:

- > Photolysis
- > Reaction with free radicals (chiefly hydroxyl)
- > Reaction with atmospheric oxidants (chiefly ozone).

The processes of photolysis and reaction with hydroxyl radicals occur only in the daytime. Hydroxyl radicals have a short atmospheric lifetime and require a continuing photolytic source to maintain their concentration.

Reference species for atmospheric reactivity selected for this study are as follows:

- > Butane
- > Propylene
- > Formaldehyde.

Butane is used when a species is OH• reactive; propylene is used when a species is reactive to O_3; formaldehyde is the reference species for photolysis. Propylene is approximately seven times as reactive to OH• as butane (EPA, 1977).

The concentration of OH• assumed for the daylight hours is 5×10^6 molecule cm^{-3}, or 2×10^{-7} ppm (Wang et al., 1975). Ozone background is assumed to be 0.04 ppm. The decay rate for butane due to OH• reactions is 8.4×10^{-4} min^{-1}. The propylene decay rate due to oxidation by O_3 is 6×10^{-4} min^{-1}.

The photolytic decay rate of formaldehyde, averaged over the daylight hours at conditions near the equinox, is about 10^{-3} min^{-1}. The midday decay rate is about twice this figure. At the summer solstice, the daily decay rate is larger owing to increased duration of the day, but the maximum photolytic decay rate for the summer is still only about 2×10^{-3} min^{-1}; at solar zenith angles below 20°, photolysis rates become nearly constant (Killus et al., 1977).

Decay Rates for Classes of Compounds

The 35 compounds assessed in this study may be divided into six general categories (Table 8) on the basis of their general structure and the data available for each compound. The six categories are as follows:

- Solid substances for which no gas phase chemistry applies; all of these substances are metals except for TCDD (Dioxin).
- Well characterized compounds, i.e., substances for which some laboratory data exist as a basis for our estimates.
- Methane analogues, which are compounds with electronic configurations similar to methane and which are, therefore, quite unreactive.
- Aromatic compounds, with reactivities assumed to be similar to benzene or toluene.
- Formation products, which are compounds formed by atmospheric reaction.
- Miscellaneous.

The last two categories need further explanation. In the "Miscellaneous" grouping, four of the compounds--allyl chloride, chloroprene, hexachloropentadiene, and phosgene--are chlorine substituted compounds of hydrocarbons with high reactivity. Although chlorine substitution is expected to modify reactivity somewhat (Gay et al., 1976), we may say with some confidence that the reactivity of these compounds is also high. The reactivity of these four compounds is, to that extent, better characterized than for the other miscellaneous compounds. Estimates of the reactivity of the remaining four compounds may be in error to a substantial degree.

For the "formation products" category, the two nitroso-compounds may be formed from the nighttime reaction of nitrous acid (HONO) and precursor amines that have been inventoried. We have estimated the possible produc-

TABLE 8. DECAY RATE ESTIMATION CATEGORIES FOR 35 COMPOUNDS

Category					
Solids*	Well Characterized Compounds	Methane Analogues	Aromatics†	Formation Products	Miscellaneous
Beryllium	Acetaldehyde	Carbon tetrachloride	Benzyl chloride	Nitrosomorpholine	Allyl chloride
Dioxin§	Acrolein	Chloroform	Chlorobenzene	Dimethylnitrosamine	Chloroprene
Manganese	Cresols	Methylene chloride	Dichlorobenzenes	(Acetaldehyde)	Epichlorohydrin
Nickel	Formaldehyde	1,1,1, Trichloroethane	Nitrobenzene	(Cresols)	Ethylene oxide
	Toluene		Phenol	(Formaldehyde)	Hexachlorocyclopentadiene
	Trichloroethylene			(Phosgene)	PCBs
	Xylenes			(Ethylene oxide)	Phosgene
				(Propylene oxide)	Propylene oxide

---

* No gas phase reactions.

† Benzene analogues.

§ 2,3,7,8-TCDD

Source: Systems Applications, Incorporated, review of species characteristics.

tion rate for these nitroso-compounds. Photolysis of HONO and nitroso--compounds precludes the occurrence of significant concentrations of these compounds during the day.

Nitrous acid and dimethylamine react to yield dimethylnitrosamine and water (Lucas, 1933):

$$(CH_3)_2NH + HONO \rightarrow (CH_3)_2NNO + H_2O \quad ,$$

Knowledge of the HNO_2 concentration, the dimethylamine concentration, and the rate of disappearence of dimethylamine, combined with the assumption of the bimolecular reaction expressed above; allows a rate constant to be calculated for the expression:

$$-\frac{d(CH_3)_2NH}{dt} = K \cdot P_{(CH_3)_2NH} \cdot P_{HONO} \quad .$$

The value was estimated to be $K = 0.08\ ppm^{-1}\ min^{-1}$ (Hanst et al., 1977). Assuming a homogeneous reaction, with a 100 percent yield of dimethylnitrosamine, the formation rate under normal atmospheric conditions can be estimated.

Nitrous oxide and nitrogen dioxide are two other pollutants of concern here. These two species, in the presence of water vapor cause the gas-phase formation of nitrous acid:

$$NO + NO_2 + H_2O \rightarrow 2HNO_2 \quad .$$

The equilibrium constant at 23°C has been estimated by Calvert et al. (1975) to be:

$$Keq = \frac{P_{HNO_2}{}^2}{P_{NO} \cdot P_{NO_2} \cdot P_{H_2O}} = 1.5 \times 10^{-6}\ ppm^{-1} \quad .$$

By assuming a moderatedly polluted urban air mix with a 1:1 mixture of NO and NO_2 of 0.05 ppm total and water vapor of 13,000 ppm, Hanst et al. (1977) have estimated the typical nighttime nitrous acid concentration to be 0.0035 ppm. This value was used here, together with the bimolecular formation expression in estimating the pseudo-first order reaction rate constant. It was estiamted to be:

$$\frac{d(CH_3)_2NNO}{dt} = K \cdot P_{HONO} \cdot P_{(CH_3)_2NH} \quad .$$

$$= (0.00028\ min^{-1})\ P_{(CH_3)_2NH} \quad .$$

This rate constant applies only in the nighttime. In sunlight, both the nitrous acid and dimethylnitrosamine would be destroyed by photolysis much faster they can be formed.

Because of the chemical similarity of dimehtylamine and morpholine, the same approach used for eatimating the ambient concentration of nitrosomorpholine. It should be noted that because of the cyclic structure of morpholine, the lone pair of electrons of the nitrogen atom are more susceptible to electrophilic attack, and therefore, the formation of nitrosomorpholine from reaction between morpoline and nitrous acid should proceed faster than the formation N,N-dimethylnitrosamine from reaction between dimethylamine and nitrous acid. However, there is no adequate data available to estimate the pseudo-first order formation rate constant for nitrosomorpholine, the estimate for dimethylnitrosamine was taken to be the same as for nitrosomorpholine.

A summary of estimated relative reactivity for each studied chemical is presented in Table 9. Also included in this table are the day and nighttime net effective decay rates based on the relative reactivities.

To treat the formation reactions of the remaining compounds in the formation products category is beyond the scope of this work. Relatively sophisticated photochemical models would be required for such an undertaking, and a full accounting of compounds not inventoried in this project would be required. For acetaldehyde, formaldehyde, and phosgene, in particular, this omission is unfortunate. Formaldehyde, for example, is emitted as roughly 1 to 2 percent of automobile exhaust, whereas the photochemical equilibrium for the compound is roughly twice this amount. Consequently, on a day of high photochemical reactivity, more than half the population exposure to formaldehyde may come from secondary formation. Similar inferences apply to acetaldehyde and phosgene. Phosgene is one of the major termination products of the decay of chlorinated hydrocarbons.

TABLE 9. PHOTOCHEMICAL REACTIVITIES OF SELECTED CHEMICALS

Chemical Species	Reactivity Toward OH- (XButane)	O_3 (XPropylene)	Photolysis (XFormaldehyde)	Reaction Rate Constant Daytime	Nighttime
Acetaldehyde	4	0	0.5	7.3×10^{-5}	0
Acrolein	0.5	0.5	5	1.6×10^{-4}	5.0×10^{-6}
Allyl Chloride	2	0.15	0	3.0×10^{-5}	1.5×10^{-6}
Benzyl Chloride	2	0	0	2.8×10^{-5}	0
Beryllium	0	0	0	0	0
Bis-chloromethyl ether (BCME)	1	0	0	8.4×10^{-4}	0
Carbon Tetrachloride	0	0	0	0	0
Chlorobenzene	0.33	0	0	4.67×10^{-6}	0
Chloroform	0	0	0	0	0
Chloromethyl methyl ether (CMME)	1	0	0	8.4×10^{-4}	0
Chloroprene	4.0	2	0	7.6×10^{-5}	2.0×10^{-5}
m-Cresol	12	0.1	0	1.68×10^{-4}	1.0×10^{-6}
p-Cresol	10	0.1	0	1.41×10^{-4}	1.0×10^{-6}
o-Cresol	10	0.1	0	1.41×10^{-4}	1.0×10^{-6}
o-Dichlorobenzene	0.5	0.05	0	7.5×10^{-6}	5.0×10^{-7}
p-Dichlorobenzene	0.5	0.05	0	7.5×10^{-6}	5.0×10^{-7}
Dimethylnitrosamine	--*	--	--	--	--
Dioxin (2,3,7,8-TCDD)	--	--	--	--	--
Epichlorohydrin	--	--	--	--	--
Ethylene oxide	1	0	0	1.4×10^{-5}	0
Formaldehyde	3	0	1	4.2×10^{-5}	0
Hexachlorocyclopentadiene	--	--	--	--	--
Manganese	0	0	0	0	0
Methyl chloroform	0	0	0	0	0
Methylene chloride	0	0	0	0	0

TABLE 9. PHOTOCHEMICAL REACTIVITIES OF SELECTED CHEMICALS - Cont'd

	Reactivity Toward			Reaction Rate Constant	
Chemical Species	OH- (XButane)	O_3 (XPropylene)	Photolysis (XFormaldehyde)	Daytime	Nighttime
Methyl iodide	0	0	0.05	$5x10^{-5}$	0
Nitrosomopholine	--	--	--	--	--
Nickel	0	0	0	0	0
Nitrobenzene	0.5	0	0	$4.2x10^{-4}$	0
2-Nitropropane	--	--	--	--	--
PCB	0.05	0	0	$7.0x10^{-5}$	0
Phenol	2	0.15	0	$2.95x10^{-5}$	$1.5x10^{-6}$
Phosgene	--	--	--	--	--
Propylene oxide	--	--	--	$1.4x10^{-5}$	0
Toluene	2	0	0	$2.8x10^{-5}$	0
Trichloroethylene	2	0	0	$2.8x10^{-5}$	0
m-Xylene	8	0	0	$1.12x10^{-4}$	0
p-Xylene	4	0	0	$1.12x10^{-4}$	0
o-Xylene	8	0	0	$5.6x10^{-5}$	0

---

*reactivity unknown

TABLE 10. LOCATION AND RECORDING PERIOD OF STAR DISPERSION DATA FILES AS REPROCESSED FOR USE IN HUMAN EXPOSURE DISPERSION STUDIES

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
1	3133	YUCCA FLATS	NV	36 57	116 3	61/12	64/11
2	3813	MACON	GA	32 42	83 39	67/ 1	71/12
3	3816	PADUCAH	KY	37 4	88 46	60/ 1	64/12
4	3820	AUGUSTA	GA	33 22	81 58	70/ 1	74/12
5	3822	SAVANNAH	GA	32 8	81 12	69/ 1	73/12
6	3855	PENSACOLA	FL	30 21	87 19	67/ 1	71/12
7	3872	BECKLEY	WV	37 47	81 7	71/ 1	75/12
8	3927	FT WORTH	TX	32 54	97 2	71/ 1	75/12
9	3937	LAKE CHARLES	LA	30 7	93 13	70/ 1	74/12
10	4739	BELMAR	NJ	40 11	74 4	55/ 1	59/12
11	4743	PORTSMOUTH	NH	43 5	70 49	69/ 1	69/12
12	4751	BRADFORD	PA	41 48	78 38	70/ 1	74/12
13	12810	TAMPA	FL	27 51	82 31	65/ 1	69/12
14	12834	DAYTONA	FL	29 11	81 3	67/ 1	71/12
15	12835	FT MYERS	FL	26 35	81 52	69/ 1	73/12
16	12839	MIAMI	FL	25 48	80 16	70/ 1	74/12
17	12841	ORLANDO	FL	28 27	81 18	60/ 1	64/12
18	12842	TAMPA	FL	27 58	82 32	69/ 1	73/12
19	12844	WEST PALM B.	FL	26 41	80 6	70/ 1	70/12
20	12906	HOUSTON	TX	29 37	95 10	66/ 1	70/12
21	12917	PRT ARTHUR	TX	29 57	94 1	64/ 1	64/12
22	12918	HOUSTON	TX	29 39	95 17	64/ 1	68/12
23	12923	GALVESTON	TX	29 16	94 52	56/ 1	60/12
24	12925	BEEVILLE	TX	28 23	97 40	66/ 1	70/12
25	12947	COTULLA	TX	28 27	99 13	50/ 1	54/12
26	12958	NEW ORLEANS	LA	29 49	90 1	70/ 1	74/12
27	12960	HOUSTON, 12918	TX	29 59	95 22	71/ 1	75/12
28	13701	ABERDEEN	MD	39 28	76 10	55/ 1	57/12
29	13705	WASHINGTON	DC	38 49	76 52	66/ 1	70/12
30	13707	DOVER	DE	39 8	75 28	66/ 1	70/12
31	13713	GOLDSBORO	NC	35 20	77 58	66/ 1	70/12
32	13714	FT BRAGG	NC	35 10	79 1	66/ 1	70/12
33	13717	MYRTLE BEACH	SC	33 41	78 56	66/ 1	70/12
34	13721	PATUXENT RIVER	MD	38 17	76 25	66/ 1	70/12
35	13723	GREENSBORO	NC	36 5	79 57	62/ 1	71/12
36	13728	DANVILLE	VA	36 34	79 20	68/ 1	72/12
37	13732	GORDONSVILLE	VA	38 4	78 10	50/ 1	54/12
38	13733	LYNCHBURG	VA	37 20	79 12	56/ 1	60/12
39	13734	MARTINSBURG	WV	39 24	77 59	69/ 1	73/12
40	13735	MILLVILLE	NJ	39 22	75 4	60/ 1	64/12

TABLE 10 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
41	13736	MORGANTOWN	WV	39 39	79 55	50/ 1	54/12
42	13737	NORFOLK REG	VA	36 54	76 12	65/ 1	64/12
43	13739	PHILADELPHIA	PA	39 53	75 15	67/ 1	71/12
44	13740	RICHMOND	VA	37 30	77 20	74/ 1	75/12
45	13741	ROANOKE	VA	37 19	79 58	68/ 1	72/12
46	13743	WASHINGTON DC	DC	38 51	77 2	74/ 1	74/12
47	13744	FLORENCE	SC	34 11	79 43	60/ 1	64/12
48	13749	FREDERICK	MD	39 26	77 27	49/ 1	52/12
49	13753	ATLANTIC CITY	NJ	39 27	74 35	54/ 1	58/12
50	13773	QUANTICO	VA	38 30	77 19	65/ 1	69/12
51	13802	BELLEVILLE	IL	38 33	89 51	61/ 1	70/12
52	13806	FT CAMPBELL	KY	36 40	87 29	65/ 1	69/12
53	13807	FT KNOX	KY	37 54	85 58	64/ 1	68/12
54	13815	ALBANY	GA	31 35	84 7	69/ 1	73/12
55	13820	BILOXI	MS	30 25	88 55	60/ 1	64/12
56	13824	SAVANNAH	GA	32 1	81 8	66/ 1	70/12
57	13825	COLUMBUS	MS	33 39	88 27	66/ 1	70/12
58	13840	DAYTON	OH	39 49	84 3	64/ 1	64/12
59	13850	SELMA	AL	32 20	86 59	54/ 1	58/12
60	13865	MERIDIAN	MS	32 20	88 45	66/ 1	70/12
61	13866	CHARLESTON	WV	38 22	81 36	68/ 1	73/12
62	13868	PULASKI	VA	37 8	80 41	50/ 1	54/12
63	13870	ALMA	GA	31 22	82 31	54/ 1	58/12
64	13871	ANNISTON	AL	33 35	85 51	49/ 1	54/12
65	13873	ATHENS	GA	33 57	83 19	69/ 1	73/12
66	13874	ATLANTA	GA	33 39	84 26	69/ 1	73/12
67	13877	BRISTOL	TN	36 29	82 24	60/ 1	64/12
68	13881	CHARLOTTE	NC	35 13	80 56	69/ 1	73/12
69	13882	CHATTANOOGA	TN	35 2	85 12	68/ 1	73/12
70	13889	JACKSONVILLE	FL	30 30	81 42	70/ 1	74/12
71	13891	KNOXVILLE	TN	35 49	83 59	68/ 1	73/12
72	13895	MONTGOMERY	AL	32 18	86 24	60/ 1	64/12
73	13897	NASHVILLE	TN	36 7	86 41	71/ 1	75/12
74	13921	FT LEAVENWORTH	KS	39 22	94 55	62/ 1	70/12
75	13935	ALEXANDRIA	LA	31 23	92 18	70/ 1	74/12
76	13939	GREENVILLE	MS	33 29	90 59	56/ 1	60/12
77	13941	LAKE CHARLES	LA	30 13	93 10	58/ 1	62/12
78	13942	MONROE	LA	32 31	92 3	54/ 1	58/12
79	13945	FT SILL	OK	34 39	98 24	66/ 1	70/12
80	13956	JACKSON	MS	32 20	90 13	60/ 1	64/12

TABLE 10 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
81	13957	SHREVEPORT	LA	32 28	93 49	70/ 1	74/12
82	13958	AUSTIN	TX	30 18	97 42	69/ 1	73/12
83	13960	DALLAS	TX	32 51	96 51	69/ 1	73/12
84	13961	FT WORTH	TX	32 49	97 21	49/ 1	52/12
85	13962	ABILENE	TX	32 26	99 41	67/ 1	71/12
86	13963	LITTLE ROCK	AR	34 44	92 14	66/ 1	70/12
87	13964	FT SMITH	AR	35 20	94 22	55/ 1	74/12
88	13967	OKALAHOMA CITY	OK	35 24	97 36	70/ 1	74/12
89	13968	TULSA	OK	36 12	95 54	55/ 1	74/12
90	13969	PONCA CITY	OK	36 44	97 6	49/ 1	54/12
91	13970	BATON ROUGE	LA	30 32	91 9	70/ 1	74/12
92	13972	TYLER	TX	32 22	95 24	50/ 1	54/12
93	13976	LAFAYETTE	LA	30 12	91 59	54/ 1	58/12
94	13977	TEXARKANA	AR	33 27	94 0	63/ 1	67/12
95	13983	COLUMBIA	MO	38 58	92 22	64/ 1	68/12
96	13983	KANSAS CITY	MO	39 7	94 36	64/ 1	64/12
97	13994	ST LOUIS	MO	38 45	90 23	70/ 1	74/12
98	13995	SPRINGFIELD	MO	37 14	93 23	66/ 1	70/12
99	13996	TOPEKA	KS	39 4	95 38	63/ 1	72/12
100	14607	CARIBOU	ME	46 52	68 1	53/ 1	62/12
101	14611	BRUNSWICK	ME	43 53	69 59	60/ 1	69/12
102	14622	OLD TOWN	ME	44 57	68 40	60/ 1	64/12
103	14702	BEDFORD	MA	42 28	71 17	63/ 1	67/12
104	14704	FALMOUTH	MA	41 39	70 31	60/ 1	64/12
105	14706	WRIGHTSTON	NJ	40 1	74 36	66/ 1	70/12
106	14708	HEMPSTEAD	NY	40 44	73 36	59/ 1	60/12
107	14712	READING	PA	40 23	75 58	49/ 1	49/12
108	14717	ROME	NY	43 14	75 24	66/ 1	70/12
109	14735	ALBANY	NY	42 45	73 48	60/ 1	64/12
110	14736	ALTOONA	PA	40 18	78 19	49/10	54/ 9
111	14737	ALLENTOWN	PA	40 39	75 26	64/ 1	73/12
112	14739	BOSTON	MA	42 22	71 2	66/ 1	70/12
113	14740	HARTFORD	CT	41 56	72 41	55/ 1	64/12
114	14742	BURLINGTON	VT	44 28	73 9	70/ 1	74/12
115	14745	CONCORD	NH	43 12	71 30	60/ 1	64/12
116	14747	DUNKIRK	NY	42 30	79 17	49/ 1	53/12
117	14748	ELMIRA	NY	42 10	76 54	50/ 1	54/12
118	14750	GLENS FALL	NY	43 21	73 37	50/ 1	54/12
119	14751	HARRISBURG	PA	40 13	76 51	64/ 1	73/12
120	14752	HARTFORD	CT	41 44	72 39	48/ 1	52/12

TABLE 10 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
121	14757	POUGHKEEPSIE	NY	41 38	73 53	50/ 1	54/12
122	14761	PHILIPSBURG	PA	40 53	78 5	50/ 1	54/12
123	14762	PITTSBURGH	PA	40 21	79 56	74/ 1	75/12
124	14763	PITTSFIELD	MA	42 26	73 18	48/ 1	53/12
125	14764	PORTLAND	ME	43 39	70 19	60/ 1	64/12
126	14765	PROVIDENCE	RI	41 44	71 26	64/ 1	73/12
127	14771	SYRACUSE	NY	43 7	76 7	55/ 1	64/12
128	14777	WILKES-BARRE	PA	41 20	75 44	64/ 1	73/12
129	14778	WILLIAMSPORT	PA	41 15	76 55	64/ 1	73/12
130	14790	SOUTH WEYMOUTH	MA	42 9	70 56	70/ 1	74/12
131	14793	WILLOW GROVE	PA	40 12	75 8	68/ 1	71/12
132	14806	RANTOUL	IL	40 18	88 9	58/ 1	62/12
133	14820	CLEFELAND	OH	41 24	81 51	70/ 1	74/12
134	14821	COLUMBUS	OH	40 0	82 53	70/ 1	74/12
135	14822	DETROIT CITY	MI	42 25	83 1	70/ 1	74/12
136	14825	FINDLAY	OH	41 1	83 40	50/ 1	54/12
137	14837	MADISON	WI	43 8	89 20	70/ 1	74/12
138	14839	MILWAUKEE	WI	42 57	87 54	70/ 1	74/12
139	14840	MUSKEGON	MI	43 10	86 14	74/ 1	74/12
140	14842	PEORIA	IL	40 40	89 41	70/ 1	74/12
141	14843	PERRY	OH	41 47	81 7	49/ 1	49/12
142	14845	SAGINAW	MI	43 26	83 52	49/ 1	54/12
143	14855	GLENVIEW	IL	42 5	87 50	74/ 1	74/12
144	14860	ERIE	PA	42 5	80 11	64/ 1	73/12
145	14891	MANSFIELD	OH	40 49	82 31	70/ 1	74/12
146	14895	AKRON	OH	40 55	81 26	64/ 1	73/12
147	14898	GREEN BAY	WI	44 29	88 8	69/ 1	73/12
148	14904	LINCOLN	NB	40 51	96 46	59/ 1	63/12
149	14913	DULUTH	MN	46 50	92 11	70/ 1	74/12
150	14914	FARGO	ND	46 54	96 48	70/ 1	74/12
151	14918	INT FALLS	MN	48 34	93 23	70/ 1	74/12
152	14920	LA CROSSE	WI	43 52	91 15	49/ 1	53/12
153	14922	MINNEAPOLIS	MN	44 53	93 13	65/ 1	74/12
154	14923	MOLIN	IL	41 27	90 31	70/ 1	74/12
155	14925	ROCHESTER	MN	43 55	92 30	69/ 1	73/12
156	14926	ST CLOUD	MN	45 35	94 11	67/ 1	71/12
157	14931	BURLINGTON	IA	40 47	91 7	67/ 1	71/12
158	14933	DES MOINES	IA	41 32	93 39	72/ 1	72/12
159	14935	GRAND IS	NB	40 58	98 19	64/ 1	64/12
160	14938	KIRKSVILLE	MO	40 6	92 33	50/ 1	54/12

TABLE 10 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
161	14940	MASON CITY	IA	43 9	93 20	70/ 1	74/12
162	14942	OMAHA	NB	41 18	95 54	60/ 1	64/12
163	14943	SIOUX CITY	IA	42 24	96 23	60/ 1	64/12
164	14944	SIOUX FALLS	SD	43 34	96 44	74/ 1	74/12
165	14949	OMAHA	NB	41 7	95 54	60/ 1	64/12
166	14991	EAU CLAIRE	WI	44 52	91 29	69/ 1	73/12
167	23002	ALAMOGORDO	NM	32 51	106 6	49/ 1	70/12
168	23009	ROSWELL/WALKER	NM	33 18	104 32	73/ 1	75/12
169	23023	MIDLAND	TX	31 56	102 12	60/ 1	64/12
170	23034	SAN ANGELO	TX	31 22	100 30	60/ 1	64/12
171	23039	LAS CRUCES	NM	32 22	106 29	51/ 1	55/12
172	23043	ROSWELL	NM	33 24	104 32	49/ 1	54/12
173	23044	EL PASO	TX	31 48	106 24	60/ 1	64/12
174	23047	AMARILLO	TX	35 14	101 42	55/ 1	64/12
175	23049	SANTA FE	NM	35 37	106 5	50/ 1	54/12
176	23052	RATON/CREWS	NM	36 43	104 30	49/ 1	51/12
177	23062	DENVER	CO	39 45	104 52	70/ 1	74/12
178	23064	GARDEN CITY	KS	37 56	100 43	50/ 1	54/12
179	23065	GOODLAND	KS	39 22	101 42	69/ 1	73/12
180	23066	GRAND JUNCTION	CO	39 7	108 12	60/ 1	64/12
181	23081	GALLUP	NM	35 31	108 47	73/ 1	75/12
182	23090	FARMINGTON	NM	36 45	108 14	54/ 1	64/12
183	23112	LAS VEGAS	NV	36 15	115 2	58/ 1	67/12
184	23114	EDWARDS	CA	34 54	117 52	66/ 1	70/12
185	23118	RENO/STEAD	NV	39 40	119 52	56/ 1	65/12
186	23122	SAN BERNARDINO	CA	34 6	117 14	66/ 1	70/12
187	23129	LONG BEACH	CA	33 49	118 9	49/ 1	64/12
188	23131	VICTORVILLE	CA	34 35	117 23	58/ 1	67/12
189	23136	OXNARD	CA	34 13	119 5	60/ 1	64/12
190	23152	BURBANK	CA	34 12	118 22	60/ 1	64/12
191	23154	ELY	NV	39 17	114 51	67/ 1	71/12
192	23155	BAKERSFIELD	CA	35 25	119 3	64/ 1	73/12
193	23158	BLYTHE	CA	33 37	114 43	69/ 9	74/ 8
194	23160	TUCSON	AZ	32 7	110 56	55/ 1	64/12
195	23161	DAGGET	CA	34 52	116 47	55/ 1	64/12
196	23169	LAS VEGAS	NV	36 5	115 10	60/ 1	64/12
197	23170	HANKSVILLE	UT	38 22	110 43	49/ 1	54/12
198	23174	LOS ANGELES	CA	33 56	118 24	55/ 1	64/12
199	23179	NEEDLES	CA	34 46	114 37	55/ 1	64/12
200	23183	PHOENIX	AZ	33 26	112 1	73/ 1	75/12

TABLE 10 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
201	23184	PRESCOTT	AZ	34 39	112 26	67/ 1	71/12
202	23185	RENO	NV	39 30	119 47	60/ 1	64/12
203	23188	SAN DIEGO	CA	32 44	117 1	65/ 1	74/12
204	23190	SANTA BARBARA	CA	34 26	119 50	60/ 1	64/12
205	23194	WINSLOW	AZ	35 1	110 44	49/ 1	54/12
206	23195	YUMA	AZ	32 40	114 36	67/ 1	71/12
207	23199	EL CENTRO	CA	32 49	115 41	54/ 1	58/12
208	23202	FAIRFIELD	CA	38 16	121 56	60/ 1	64/12
209	23211	SAN RAFAEL	CA	38 4	122 30	66/ 1	70/12
210	23230	OAKLAND	CA	37 44	122 12	60/ 1	64/12
211	23232	SACRAMENTO	CA	38 31	121 30	66/ 1	70/12
212	23234	SAN FRANCISCO	CA	37 37	122 23	69/ 1	73/12
213	23236	SANTA MARIA	CA	34 56	120 25	49/ 1	53/12
214	23239	ALAMEDA	CA	37 48	122 18	60/ 1	64/12
215	23244	SUNNYVALE	CA	37 25	122 4	60/ 1	64/12
216	23245	MONTERY	CA	36 35	121 52	59/ 1	63/12
217	23273	SANTA MARIA	CA	34 54	120 27	65/ 1	74/12
218	23275	UKIAH	CA	38 8	123 12	55/ 1	64/12
219	24012	DICKINSON	ND	46 47	102 48	60/ 1	64/12
220	24013	MINOT	ND	48 16	101 17	67/ 1	71/12
221	24015	AKRON	CO	40 10	103 13	50/ 1	54/12
222	24023	NORTH PLATTE	NB	41 8	100 41	69/ 1	73/12
223	24025	PIERRE	SD	44 23	100 17	67/ 1	71/12
224	24028	SCOTTSBLUFF	NB	41 52	103 36	67/ 1	71/12
225	24036	LEWISTOWN	MT	47 3	109 27	67/ 1	71/12
226	24057	RAWLINS	WY	41 48	107 12	55/ 1	64/12
227	24090	RAPID CITY	SD	44 3	103 4	67/ 1	71/12
228	24101	OGDEN	UT	41 7	111 58	65/ 1	69/12
229	24106	MT HOME	ID	43 3	115 52	65/ 1	69/12
230	24110	MOSES LAKE	WA	47 12	119 19	61/ 1	68/12
231	24118	FT BRIDGER	WY	41 24	110 25	50/ 1	54/12
232	24121	ELKO	NV	40 50	115 47	69/ 1	73/12
233	24128	WINNEMUCCA	NV	40 54	117 48	69/ 1	73/12
234	24130	BAKER	OR	44 50	117 49	60/ 1	64/12
235	24131	BOISE	ID	43 34	116 13	74/ 1	74/12
236	24135	BUTTE	MT	45 57	112 30	56/ 1	60/12
237	24137	CUTBANK	MT	48 36	112 22	49/ 1	58/12
238	24141	EPHRATA	WA	47 19	119 31	50/ 1	54/12
239	24144	HELENA	MT	46 36	112 0	58/ 1	62/12
240	24145	IDAHO FALL	ID	43 31	112 4	55/ 1	64/12

TABLE 10 (Continued)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
241	24146	KALISPELL	MT	48 18	114 16	68/ 1	72/12
242	24151	MALAD CITY	ID	42 10	112 19	48/ 1	54/12
243	24153	MISSOULA	MT	46 55	114 5	67/ 1	71/12
244	24155	PENDLETON	OR	45 51	118 61	55/ 1	64/12
245	24156	POCATELLO	ID	42 55	112 36	65/ 1	74/12
246	24157	SPOKANE	WA	47 38	117 32	74/ 1	74/12
247	24160	WALLA WALLA	WA	46 6	118 17	50/ 1	54/12
248	24203	EVERETT	WA	47 55	122 17	63/ 1	67/12
249	24207	TACOMA	WA	47 9	122 29	66/ 1	70/12
250	24217	BELLINGHAM	WA	48 48	122 32	74/ 1	74/12
251	24219	DALLESPORT	WA	45 37	121 9	64/ 1	64/12
252	24220	ELLENSBURG	WA	47 2	120 31	50/ 1	54/12
253	24221	EUGENE	OR	44 7	123 13	74/ 1	74/12
254	24225	MEDFORD	OR	42 22	122 52	70/ 1	74/12
255	24227	OLYMPIA	WA	46 58	122 54	74/ 1	74/12
256	24229	PORTLAND	OR	45 36	122 36	69/ 1	73/12
257	24230	REDMON	OR	44 16	121 9	55/ 1	64/12
258	24232	SALEM	OR	44 55	123 1	74/ 1	74/12
259	24233	SEATTLE	WA	47 27	122 18	74/ 1	74/12
260	24234	SEATTLE	WA	47 32	122 18	60/ 1	64/12
261	24241	TOLEDO	WA	46 29	122 48	50/ 1	54/12
262	24243	YAKIMA	WA	46 34	120 32	74/ 1	74/12
263	24283	ARCATA	CA	40 59	124 6	68/ 1	72/12
264	93026	DOUGLAS	AZ	31 27	109 36	50/ 1	54/12
265	93034	HOBBS	NM	32 41	103 12	49/ 1	54/12
266	93037	COLO SPRINGS	CO	38 49	104 43	74/ 1	74/12
267	93044	ZUNI	NM	35 6	108 48	67/ 1	71/12
268	93057	GRANTS	NM	35 10	107 54	54/ 1	54/12
269	93102	FALLON	NV	39 25	118 43	66/ 1	70/12
270	93106	LOS ALAMITOS	CA	33 48	118 7	65/ 1	69/12
271	93111	POINT MUGU	CA	34 7	119 7	52/ 3	72/ 2
272	93112	SAN DIEGO	CA	32 43	117 12	67/ 1	71/12
273	93214	VANDENBERG	CA	34 43	120 34	59/ 1	72/12
274	93706	HAGERSTOWN	MD	39 42	77 43	74/ 1	74/12
275	93733	FT MEADE	MD	39 5	76 46	60/ 1	64/12
276	93739	WALLOPS IS	VA	37 51	75 29	69/ 1	73/12
277	93804	SPARTANBURG	SC	34 55	81 57	57/ 1	61/12
278	93805	TALLAHASSEE	FL	30 23	84 22	72/ 1	76/12
279	93807	WINSTON SALEM	NC	36 8	80 14	60/ 1	64/12
280	93815	DAYTON	OH	39 54	84 13	70/ 1	74/12

TABLE 10 (Concluded)

NO.	CODE	SITE	STATE	LATITUDE	LONGITUDE	STARTING	ENDING
281	93817	EVANSVILLE	IN	38 3	87 32	70/ 1	74/12
282	93819	INDIANAPOLIS	IN	39 44	86 17	55/ 1	74/12
283	93820	LEXINGTON	KY	38 2	84 36	55/ 1	64/12
284	93822	SPRINGFIELD	IL	39 50	89 40	70/ 1	74/12
285	93824	CAMBRIDGE	OH	39 57	81 54	50/ 1	54/12
286	93836	BRUNSWICK	GA	31 15	81 28	69/ 1	73/12
287	93841	MILTON	FL	30 42	87 1	62/ 1	71/12
288	93842	COLUMBUS	GA	32 31	84 56	69/ 1	73/12
289	93846	ANDERSON	SC	34 30	82 43	54/ 1	58/12
290	93919	MCCOMB	MS	31 15	90 20	49/ 1	54/12
291	93950	MCALESTER	OK	34 53	95 47	54/ 1	54/12
292	93987	LUFKIN	TX	31 14	94 45	67/ 1	71/12
293	93989	QUINCY	IL	39 56	91 12	50/ 1	54/12
294	93992	ELDORADO	AR	33 13	92 48	50/ 1	54/12
295	94012	HAVRE CITY	MT	48 33	109 46	67/ 1	71/12
296	94014	WILLISTON	ND	48 11	103 38	67/ 1	71/12
297	94224	ASTORIA	OR	46 9	123 53	74/ 1	74/12
298	94225	HOQUIAM	WA	46 58	123 56	54/ 1	58/12
299	94240	QUILLAYUTE	WA	47 57	124 33	74/ 1	74/12
300	94725	MASSENA	NY	44 56	74 51	70/ 1	74/12
301	94741	TETERBORO	NJ	40 51	74 3	52/ 1	56/12
302	94745	WHITE PL	NY	41 4	73 43	68/ 1	72/12
303	94746	WORCHESTER	MA	42 16	71 52	70/ 1	74/12
304	94789	NEW YORK	NY	40 47	73 46	74/ 1	74/12
305	94790	WATERTOWN	NY	44 0	76 1	60/ 1	64/12
306	94794	UTICA	NY	43 9	75 23	50/ 1	54/12
307	94822	ROCKFORD	IL	42 12	89 6	70/ 1	74/12
308	94830	TOLEDO	OH	41 36	83 48	70/ 1	74/12
309	94836	GWINN	MI	46 21	87 24	63/ 1	67/12
310	94846	CHICAGO	IL	41 59	87 54	70/ 1	74/12
311	94910	WATERLOO	IA	42 33	92 24	60/ 1	64/12

TABLE 11. LOCATION OF SPECIFIC POINT SOURCES AND SELECTED STAR DISPERSION DATA STATION

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
1	AIR PRODUCTS	PENSACOLA, FL	30 36 29	87 8 12	3855
2	AKZONA	MCCOOK, IL	41 48 17	87 49 41	94846
3	AKZONA	MORRIS, IL	41 24 24	88 18 10	14855
4	ALLIED	DANVILLE, IL	40 8 30	87 33 45	14806
5	ALLIED	ELIZABETH, NJ	40 40 45	74 13 51	4739
6	ALLIED	EL SEGUNDO, CA	33 56 30	118 26 35	23129
7	ALLIED	FRANKFORD, PA	40 18 15	79 52 43	14762
8	ALLIED	HOPEWELL, VA	37 22 13	77 18 8	13740
9	ALLIED	MOUNDSVILLE, WV	39 54 39	80 44 49	13736
10	ALLIED	SOUTHPOINT, OH	38 25 43	82 36 0	93824
11	AMAX	PORT NICKEL, LA	29 52 35	89 57 26	12958
12	AMER CYANAMID	BOUND BROOK, NJ	40 24 45	74 33 40	94741
13	AMER CYANAMID	CHARLOTTE, NC	35 12 16	80 50 32	13881
14	AMER CYANAMID	WILLOW ISLAND, WV	39 21 50	81 18 50	13736
15	AMER. HOECHST	BATON ROUGE, LA	30 33 2	191 15 50	13970
16	AMER PETROFINA	BIG SPRINGS, TX	32 17 10	101 25 17	13962
17	AMER PETROFINA	PORT ARTHUR, TX	29 57 30	93 53 20	12917
18	AMOCO	COPPER RIVER, SC	32 45 57	79 58 28	13717
19	AMOCO	DECATUR, AL	34 36 12	86 58 42	13882
20	AMOCO	JOLIET, IL	41 26 48	88 10 41	14855
21	AMOCO	TEXAS CITY, TX	29 21 40	94 55 50	12906
22	ARCO	CHANNELVIEW, TX 2	95 0 40	950 64 31	29060
23	ARCO	HOUSTON, TX	29 42 17	95 16 1	12960
24	ASHLAND	CATLETTSBURG, KY	38 22 39	82 35 58	13866
25	ASHLAND	FORD, NJ	40 31 20	74 20 50	4739
26	ASHLAND	JANESVILLE, WI	42 41 56	89 0 10	14839
27	BASF WYANDOTTE	GEISMAR, LA	30 11 34	91 0 42	13970
28	ASHLAND	N. TONAWANDA, NY 4	25 94 50	785 52 71	47470
29	BASF WYANDOTTE	KEARNEY, NJ	40 45 53	74 9 3	4739
30	BASF WYANDOTTE	WASHINGTON, NJ	40 45 20	74 58 22	4739
31	BASF WYANDOTTE	WYANDOTTE, MI	42 12 55	83 8 35	14822
32	BETHLEHEM STEEL	SPARROWS POINT, MD	39 18 30	76 34 30	13701
33	BLUE SPRUCE	BOUND BROOK, NJ	40 32 10	74 29 18	14737
34	BORDEN	DEMOPOLIS, AL	32 30 48	27 50 6	13850
35	BORDEN	DIBOLL, TX	31 11 52	94 46 50	93987
36	BORDEN	FAYETTEVILLE, NC	35 1 43	78 51 41	13714
37	BORDEN	FREMONT, CA	37 32 6	121 57 24	23244
38	BORDEN	GEISMAR, LA	30 13 0	91 1 0	13970
39	BORDEN	KENT, WA	47 23 12	122 13 15	24233
40	BORDEN	LA GRANDE, OR	45 20 33	100 2 2	24130

TABLE 11 (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
41	BORDEN	LOUISVILLE, KY	38 12 9	85 51 49	93820
42	BORDEN	MISSOULA,MT	46 54 10	114 40 0	24146
43	BORDEN	SHEBOYGAN, WI	43 45 26	87 46 17	14898
44	BORDEN	SPRINGFIELD, OR	44 2 60	122 59 6	24221
45	BORG-WARNER	MORGANTOWN, WV	39 40 39	80 58 34	13736
46	BRUSH WELLMAN	ELMORE, OH	41 28 6	83 16 37	94830
47	BRUSH WELLMAN	HAMPTON, NJ	40 42 32	74 57 41	94741
48	BRUSH WELLMAN	READING, PA	40 46 45	76 11 10	14712
49	E.R.CARPENTER	BAY PORT, TX	29 43 20	94 54 0	12906
50	CELANESE	BAY CITY, TX	28 51 45	96 1 0	12923
51	CELANESE	BISHOP, TX	27 34 6	97 49 27	12925
52	CELANESE	CLEAR LAKE, TX	29 37 17	95 3 51	12906
53	CELANESE	LINDEN, NJ	40 37 18	74 15 53	94741
54	CELANESE	LOUISVILLE, KY	38 11 0	85 50 0	93820
55	CELANESE	NEWARK, NJ	40 43 30	74 7 25	94741
56	CELANESE	ROCK HILL, SC	34 57 25	80 57 32	93804
57	CHARTER OIL	HOUSTON, TX	29 42 50	95 15 12	12906
58	CHEMBOND	SPRINGFIELD, OR	44 2 60	122 59 6	24221
59	CHEMBOND	WINNIFIELD, LA	31 54 49	92 40 35	13942
60	CHEMTRON	LAPORTE, TX	29 39 20	95 2 18	12906
61	CHEVRON	PASCAGOULA, MS	30 19 4	88 28 37	13820
62	CHEVRON	RICHMOND, CA	37 56 12	122 20 48	23239
63	CIBA-GEIGY	TOMS RIVER, NJ	39 59 20	74 22 33	14706
64	CLARK	BLUE ISLAND, IL	41 39 21	87 41 56	14855
65	COASTAL STATES	CORPUS CHRISTI, TX	27 48 43	97 26 28	12925
66	CONTINENTAL	CLIFTON, NJ	40 43 34	74 7 26	94741
67	CONTINENTAL	NEWARK, NJ	40 43 34	74 7 26	94741
68	COS-MAR	CARVILLE, LA	30 13 30	91 4 0	13970
69	CPC	LYNDHURST, NJ	40 47 30	74 4 34	94741
70	CROWLY TAR	HOUSTON, TX	29 43 50	95 14 20	12906
71	CROWN OIL	PASADENA, TX	29 44 40	95 10 30	12906
72	DEGUSSA	THEODORE, AL	30 33 6	88 10 35	3855
73	DENKA	HOUSTON, TX	29 41 31	95 15 12	12906
74	DIAMND SHAMROCK	BELLE, WV	38 14 9	81 32 38	13866
75	DOW	FREEPORT, TX	28 59 30	95 23 35	12923
76	DOW	MIDLAND, MI	43 35 28	84 13 8	14845
77	DOW	PITTSBURG, CA	37 59 34	121 54 56	23202
78	DOW	PLAQUEMINE, LA	30 19 0	91 15 0	13970
79	DU PONT	ANTIOCH, CA	37 59 37	121 52 0	23202
80	DU PONT	BEAUMONT, TX	30 0 51	94 1 40	12917

TABLE 11(Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
81	DU PONT	BELLE, WV	38 13 6	81 34 12	13866
82	DU PONT	CORPUS CHRISTI,TX	27 53 0	97 15 0	12925
83	DU PONT	DEEPWATER, NJ	39 41 25	75 30 35	13739
84	DU PONT	GIBBSTOWN, NJ	39 49 50	75 15 50	13739
85	DU PONT	HEALING SPRING, NC	35 1 56	80 10 30	13714
86	DU PONT	HOUSTON, TX	29 42 4	95 2 5	12906
87	DU PONT	LAPLACE, LA	30 4 0	90 32 0	12958
88	DU PONT	LAPORTE, TX	29 42 4	95 2 5	12906
89	DU PONT	LINDEN, NJ	40 36 2	74 12 8	94741
90	DU PONT	LOUISVILLE, KY	38 11 51	85 54 13	13807
91	DU PONT	MONTAGUE, MI	43 24 10	86 23 40	14840
92	DU PONT	OLD HICKORY, TN	36 16 24	86 34 12	13897
93	DU PONT	PARKERSBURG, WV	39 15 27	81 32 52	13866
94	DU PONT	TOLEDO, OH	41 39 22	83 33 20	94830
95	DU PONT	VICTORIA, TX	28 40 29	96 57 21	12923
96	DU PONT	WILMINGTON, NC	34 10 0	77 56 6	13717
97	EASTMAN KODAK	COLUMBIA, SC	33 59 50	81 4 17	13744
98	EASTMAN KODAK	KINGSPORT, TN	36 31 41	82 12 22	13877
99	EASTMAN KODAK	LONGVIEW, TX	32 25 55	94 41 6	13972
100	EASTMAN KODAK	ROCHESTER, NY	43 12 1	77 37 58	14771
101	EMERY	MAULDIN, SC	34 48 16	82 16 9	93804
102	EMERY	SANTAFE SPRINGS, CA	33 55 30	118 5 40	23174
103	ETHYL	BATON ROUGE, LA	30 18 0	91 8 0	13970
104	EXXON	BATON ROUGE, LA	30 9 10	90 54 20	13970
105	EXXON	BAYTOWN, TX	29 44 50	95 1 0	12906
106	EXXON	BAYWAY, NJ	40 38 46	74 11 48	94741
107	FALLEK	TUSCALOOSA, AL	33 11 0	87 34 50	93806
108	FERRO	SANTA FE S. , CA	33 56 30	118 4 18	93106
109	FIRST CHEMICAL	PASCAGOULA, MS	30 21 20	88 32 55	13820
110	FMC	BALIMORE, MD	39 14 50	76 35 30	13701
111	FMC	BUFFALO, NY	42 59 10	78 50 30	14747
112	FMC	MIDDLEPORT, NY	43 12 21	78 29 23	14747
113	FMC	NITRO, WV	38 25 33	81 50 5	13866
114	FMC	SO CHARLESTON, WV	38 22 10	81 40 3	13866
115	GAF	CALVERT CITY, KY	37 2 50	88 21 12	3816
116	GAF	LINDEN, NJ	40 38 19	74 15 26	94741
117	GAF	TEXAS CITY, TX	29 25 29	94 58 7	12923
118	GEN ELECTRIC	MOUNT VERNON, IN	37 56 42	87 34 25	93817
119	GEORGIA-PACIFIC	ALBANY, OR	44 37 7	123 5 13	24232
120	GEORGIA-PACIFIC	COLUMBUS, OH	39 53 7	82 56 45	14821

TABLE 11 (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
121	GEORGIA-PACIFIC	COOS BAY, OR	42 27 26	124 10 47	24283
122	GEORGIA-PACIFIC	CROSSETT, AR	33 8 36	93 2 11	93992
123	GEORGIA-PACIFIC	LUFKIN, TX	31 21 0	94 47 0	93987
124	GEORGIA-PACIFIC	PLAQUEMINE, LA	30 15 0	91 11 0	13970
125	GEORGIA-PACIFIC	RUSSELVILLE, SC	33 20 52	79 58 0	13717
126	GEORGIA-PACIFIC	TAYLORVILLE, MS	31 51 0	89 25 0	13865
127	GEORGIA-PACPFIC	VIENNA, GA	32 7 30	83 49 0	13815
128	GETTY OIL	EL DORADO, KS	37 47 10	96 52 0	13969
129	W. R. GRACE	NASHUA, NH	42 46 0	71 27 52	14745
130	GULF	ALLIANCE, LA	29 50 0	90 0 19	12958
131	GULF	CEDAR BAYOU, TX	29 49 29	94 55 10	12923
132	GULF	JERSEY CITY, NJ	40 43 2	74 6 14	94741
133	GULF	PHILADELPHIA, PA	39 54 0	75 12 30	13739
134	GULF	VICKSBURG, MS	32 17 0	90 54 0	13956
135	HANNA MINING	RIDDLE, OR	42 55 2	123 25 0	24221
136	HERCULES	WILMINGTON, NC	34 19 27	77 46 56	13717
137	HERCULES	BRUNSWICK, GA	31 7 55	81 28 5	93836
138	HERCULES	HARBOR BEACH, MI	43 51 7	82 42 8	14845
139	HERCULES	HOPEWELL, VA	37 15 34	77 17 14	13740
140	HERCULES	LOUISIANA, MO	39 26 24	91 3 37	93989
141	HERCULES	PARLIN, NJ	40 31 30	74 27 10	94741
142	HERCULES	WILMINGTON, NC	34 19 9	77 59 23	13748
143	HEXCEL	LODI, NJ	40 52 0	74 6 50	94741
144	HIGHPOINT	HIGH POINT, NC	35 59 10	80 0 37	93807
145	HODAG	STOKIE, IL	42 1 50	87 43 39	14855
146	HOOKER	MONTAGUE, MI	43 24 45	86 22 30	14840
147	HOOKER	NIAGARA FALLS, NY	43 3 2	79 0 27	14747
148	HOOKER	N TONAWANDA, NY	43 2 47	78 51 44	14747
149	ICC	NIAGARA FALLS, NY	43 3 33	79 0 55	14747
150	IMC	SEIPLE, PA	40 38 12	75 31 38	14737
151	IMC	STERLINGTON, LA	32 43 25	92 8 56	13942
152	INTER MINERAL	TERRE HAUTE, IN	39 27 7	87 25 2	13806
153	JEFFERSON	AUSTIN, TX	30 20 0	97 14 15	13958
154	JEFFERSON	CONROE, TX	30 18 50	95 23 6	12960
155	JEFFERSON	PORT NECHES, TX	29 57 45	93 56 0	12917
156	JONES & LAUGHLI	ALIQUIPPA, PA	40 35 54	80 14 24	14762
157	KALAMA	EDDYSTONE, PA	39 50 58	75 20 0	13739
158	KALAMA	KALAMA, WA	46 0 54	122 51 5	24229
159	KAWECKI BERYLCO	HAZELTON, PA	40 21 28	75 57 10	14737
160	KAWECKI BERYLCO	READING, PA	40 47 32	76 11 50	14712

TABLE 11 (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
161	H. KOHNSTAM	CAMDEN, NJ	39 54 42	75 8 53	13739
162	H. KOHNSTAM	CLEARING, IL	41 49 10	87 45 40	14855
163	KOPPERS	CICERO, IL	41 48 44	87 45 4	14855
164	KOPPERS	FOLLANSBEE, WV	40 23 10	80 35 7	14762
165	KOPPERS	OIL CITY, PA	41 29 30	79 43 20	14860
166	LACHAT	MEQUON, WI	43 13 56	88 2 30	14839
167	LONZA	MAPLETON, IL	40 34 0	89 43 1	14842
168	MAGNA	HOUSTON, TX	29 40 10	95 23 30	12906
169	MAK CHEMICAL	MUNCIE, IN	40 12 17	85 20 38	93815
170	MALLINCKRODT	LODI, NJ	40 52 56	74 5 46	94741
171	MERICHEM	HOUSTON, TX	29 45 36	95 10 48	12906
172	MILLIKEN	INMAN, SC	34 56 10	82 6 29	93804
173	MINEREC	BALTIMORE, MD	39 14 11	76 34 41	13701
174	3M	DECATUR, AL	34 38 39	87 2 25	13882
175	MOBAY	BAYTOWN, TX	29 45 30	94 54 25	12906
176	MOBAY	NEW MARTNSVILLE, WV	39 44 50	80 50 50	13736
177	MOBILE	BEAUMONT, TX	30 4 14	94 3 40	12917
178	MONSANTO	ADDYSTON, OH	39 7 30	84 42 58	93815
179	MONSANTO	ALVIN, TX	29 14 55	95 12 45	12906
180	MONSANTO	BRIDGEPORT, NJ	39 47 33	75 23 45	13739
181	MONSANTO	CHOCOLATE BAYOU, TX	29 14 55	95 12 45	12906
182	MONSANTO	EUGENE, OR	44 2 59	123 8 19	24221
183	MONSANTO	KEARNEY, NJ	40 46 12	74 9 8	94741
184	MONSANTO	LULING, LA	29 55 10	90 22 30	12958
185	MONSANTO	NITRO, WV	38 24 26	81 51 26	13866
186	MONSANTO	SAUGET, IL	38 35 31	90 10 11	13994
187	MONSANTO	SPRINGFIELD, MA	42 9 33	72 29 9	14763
188	MONSANTO	ST. LOUIS, MO	38 34 37	90 11 42	13994
189	MONSANTO	TEXAS CITY, TX	29 22 45	94 33 30	12923
190	MONTROSE	HENDERSON, NV	36 3 32	114 58 34	23112
191	MONTROSE	TORRANCE, CA	33 46 58	118 22 6	23129
192	NALCO	SUGAR LAND, TX	29 37 10	95 28 32	12906
193	NAPP	LODI, NJ	40 52 30	74 6 14	94741
194	NATIONAL STARCH	SALISBURY, NC	35 43 36	80 28 19	13723
195	NEPARA	HARRIMAN, NY	41 16 45	74 8 24	14757
196	NORDA	BOONTON, NJ	40 54 13	74 24 44	94741
197	N PETROCHEMICAL	EAST MORRIS, IL	41 24 8	88 17 18	94846
198	OCCIDENTAL	N TONAWANDA, NY	43 2 47	78 51 44	14747
199	OLIN	ASHTABULA, OH	41 53 7	80 45 50	14843
200	OLIN	BRANDENBURG, KY	38 0 27	86 6 50	13807

TABLE 11 (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
201	OLIN	LAKE CHARLES, LA	30 13 55	93 15 57	3937
202	ORBIS	NEWARK, NJ	40 41 16	74 12 17	94741
203	OWENS-CORNING	NEWARK, OH	40 5 30	82 26 0	93824
204	OXIRANE	BAYPORT, TX	29 37 26	95 3 7	12906
205	OXIRANE	CHANNELVIEW, TX	29 48 50	95 7 30	12906
206	PACIFIC RESINS	EUGENE, OR	44 1 0	123 5 5	24221
207	PBI-GORDON	KANSAS CITY, MO	39 8 53	94 40 59	13988
208	PELRON	LYONS, IL	41 44 56	87 49 4	94846
209	PENNWALT	CALVERT CITY, KY	37 3 18	88 19 40	3816
210	PERSTORP	TOLEDO, OH	41 43 10	83 31 28	94830
211	PETROLITE	BREA, CA	33 53 30	117 58 45	23174
212	PETROLITE	ST LOUIS, MO	38 41 50	90 12 0	13994
213	PFIZER	TERRE HAUTE, IN	39 26 1	87 24 22	93819
214	PLASTICS ENG	SHEBOYGAN, WI	43 45 0	87 47 0	14839
215	PPG	BARBERTON, OH	41 0 37	81 36 29	14895
216	PPG	BEAUMONT, TX	30 3 40	94 2 30	12917
217	PPG	CIRCLEVIEW, OH	39 36 5	82 57 34	93824
218	PPG	LAKE CHARLES, LA	30 13 14	93 16 54	3937
219	PPG	NEW HARTNSVILLE, WV	39 47 22	80 51 27	13736
220	PROCTR & GAMBLE	MEMPHIS, TN	35 10 40	89 56 30	13963
221	PUBLICKER	PHILADELPHIA, PA	39 53 30	75 12 18	13739
222	QUAKER OATS	MEMPHIS, TN	35 10 30	89 56 56	13963
223	QUINTANA-HOWELL	CORPUS CHRISIT, TX	27 48 35	97 27 30	12925
224	REICHHOLD	ANDOVER, MA	42 8 30	71 8 28	14739
225	REICHHOLD	AZUSA, CA	34 7 52	117 53 51	23174
226	REICHHOLD	CARTERET, NJ	40 35 56	74 13 13	94741
227	REICHHOLD	DETROIT, MI	42 28 17	83 7 52	14822
228	REICHHOLD	HAMPTON, SC	32 53 33	81 6 10	3820
229	REICHHOLD	HOUSTON, TX	29 45 10	95 10 15	12906
230	REICHHOLD	KANSAS CITY, KS	39 9 28	94 37 41	13988
231	REICHHOLD	MALVERN, AR	34 24 9	92 48 45	13963
232	REICHHOLD	MONCURE, NC	35 31 18	79 4 52	13714
233	REICHHOLD	TACOMA, WA	47 16 11	122 22 57	24207
234	REICHHOLD	TUSCALOOSA, AL	33 12 3	87 34 0	13825
235	REICHHOLD	WHITE CITY, OR	42 26 18	122 7 7	24225
236	REILLY TAR	INDIANAPOLIS, IN	39 42 0	86 14 0	93819
237	RIVERDALE	CHICAGO HEIGHT, IL	41 30 30	87 38 11	94846
238	ROHM & HAAS	DEER PARK, TX	29 43 30	95 6 15	12906
239	ROHM & HAAS	PHILADELPHIA, PA	39 54 50	75 11 30	13739
240	RUBICON	GEISMAR, LA	30 12 0	91 11 30	12958

TABLE 11 (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
241	SCHENECTADY	OYSTER CREEK, TX	29 58 21	95 20 38	12960
242	SCHENECTADY	ROTTERDAM JUNC, NY	42 47 22	73 43 12	14735
243	SCHER BROTHERS	CLIFTON, NJ	40 42 14	74 10 17	94741
244	SHELL	DEER PARK, TX	29 42 55	95 7 34	12906
245	SHELL	GEISMAR, LA	30 11 0	90 59 0	12958
246	SHELL	MARTINEZ, CA	38 0 5	122 6 40	23202
247	SHELL	NORCO, LA	30 0 11	90 23 42	12958
248	SHELL	ODESSA, TX	31 49 14	102 19 53	23023
249	SHEREX	JANESVILLE, WI	42 40 47	89 0 30	14837
250	SHERWIN WILLIAM	CHICAGO, IL	41 43 4	87 36 30	94846
251	SPECIALTY ORGAN	IRWINDALE, CA	34 6 30	117 55 48	23152
252	STANDARD	RICHMOND, TX	37 56 12	122 20 48	12906
253	STAND CHLORINE	DELAWARE CITY, DE	39 33 54	75 38 47	94741
254	STAUFFER	COLD CREEK, AL	30 58 30	88 1 16	93841
255	STAUFFER	GALLIPOLIS FY., WV	38 46 40	82 10 54	13866
256	STAUFFER	EDISON, NJ	40 29 23	74 23 3	94741
257	STAUFFER	LEMOYNE, AL	30 53 50	87 58 50	93841
258	STAUFFER	LOUISVILLE, KY	38 12 9	85 51 49	93820
259	STEPAN	MILLSDALE, IL	41 26 3	88 9 48	94846
260	STERLING	CINCINNATI, OH	39 5 15	84 33 9	13840
261	STINSON	ANACORTES, WA	48 28 31	122 32 48	24217
262	SUN OIL	CLAYMONT, DE	39 48 20	75 25 40	94741
263	SUN OIL	CORPUS CHRISTI, TX	27 50 0	97 31 25	12925
264	SUN OIL	MARCUS HOOK, PA	39 48 45	75 24 51	13739
265	SUN OIL	TOLEDO, OH	41 36 52	83 31 40	94830
266	SUN OIL	TULSA, OK	36 8 18	96 1 18	13968
267	TELEDYNE MCCORM	HOLLISTER, CA	36 50 6	121 25 0	2324
268	TENN EASTMAN	KINGSPORT, TN	36 31 27	88 32 29	3816
269	TENNECO	CHALMETTE, LA	30 3 30	89 58 30	12958
270	TENNECO	FORDS, NJ	40 30 50	74 19 17	94741
271	TENNECO	GARFIELD, NJ	40 52 28	74 6 47	94741
272	TEXAS EASTMAN	LONGVIEW, TX	32 25 55	94 41 6	13972
273	TOMS RIVER	TOMS RIVER, NJ	39 58 14	74 12 30	14706
274	UNION CARBIDE	AMBLER, PA	40 1 48	75 13 41	13739
275	UNION CARBIDE	BOUND BROOK, NJ	40 33 32	74 31 18	94741
276	UNION CARBIDE	FREMONT, CA	37 28 38	122 0 40	23244
277	UNION CARBIDE	INSTITUTE, WV	38 23 2	81 47 24	13866
278	UNION CARBIDE	SEADRIFT, TX	28 30 31	96 46 18	12923
279	UNION CARBIDE	SO CHARLESTON, WV	38 19 35	81 40 29	13866
280	UNION CARBIDE	ST. JOSEPH, MO	39 45 36	94 50 46	13921

TABLE 11 (Concluded)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION
281	UNION CARBIDE	TAFT, LA	29 58 0	90 27 0	13970
282	UNIROYAL	GEISMAR, LA	30 13 30	91 0 15	12958
283	UOP	E RUTHERFOLD, NJ	40 49 46	74 5 30	94741
284	UPJOHN	LAPORTE, TX	29 42 26	95 4 29	12906
285	U. S. STEEL	CLAIRTON, PA	40 18 15	79 52 43	14762
286	U. S. STEEL	HAVERHILL, OH	38 34 52	82 49 36	13866
287	US STEEL	GENEVA,VT	40 19 1	114 42 92	41010
288	VAN DE MARK	LOCKPORT, NY	43 11 8	78 42 40	14747
289	VELSICOL	BEAUMONT, TX	29 58 16	94 3 17	12917
290	VELSICOL	CHATTANOOGA, TN	35 2 31	85 16 36	13882
291	VELSICOL	MARSHALL, IL	39 23 0	87 42 30	93819
292	VELSICOL	MEMPHIS, TN	35 9 50	89 57 45	13963
293	VERTAC	JACKSONVILLE, AR	34 55 36	92 4 56	13963
294	VERTAC	WEST HELENA, AR	34 36 10	90 33 45	13939
295	VULCAN	GEISMAR, LA	30 10 0	90 59 0	12958
296	VULCAN	WICHITA, KA	37 36 58	97 18 30	13969
297	WITCO	CLEARING, IL	41 48 2	87 46 39	94846
298	WITCO	HOUSTON, TX	29 34 45	95 26 0	12906
299	WRIGHT	RIEGELWOOD, NC	34 19 22	78 12 9	13717

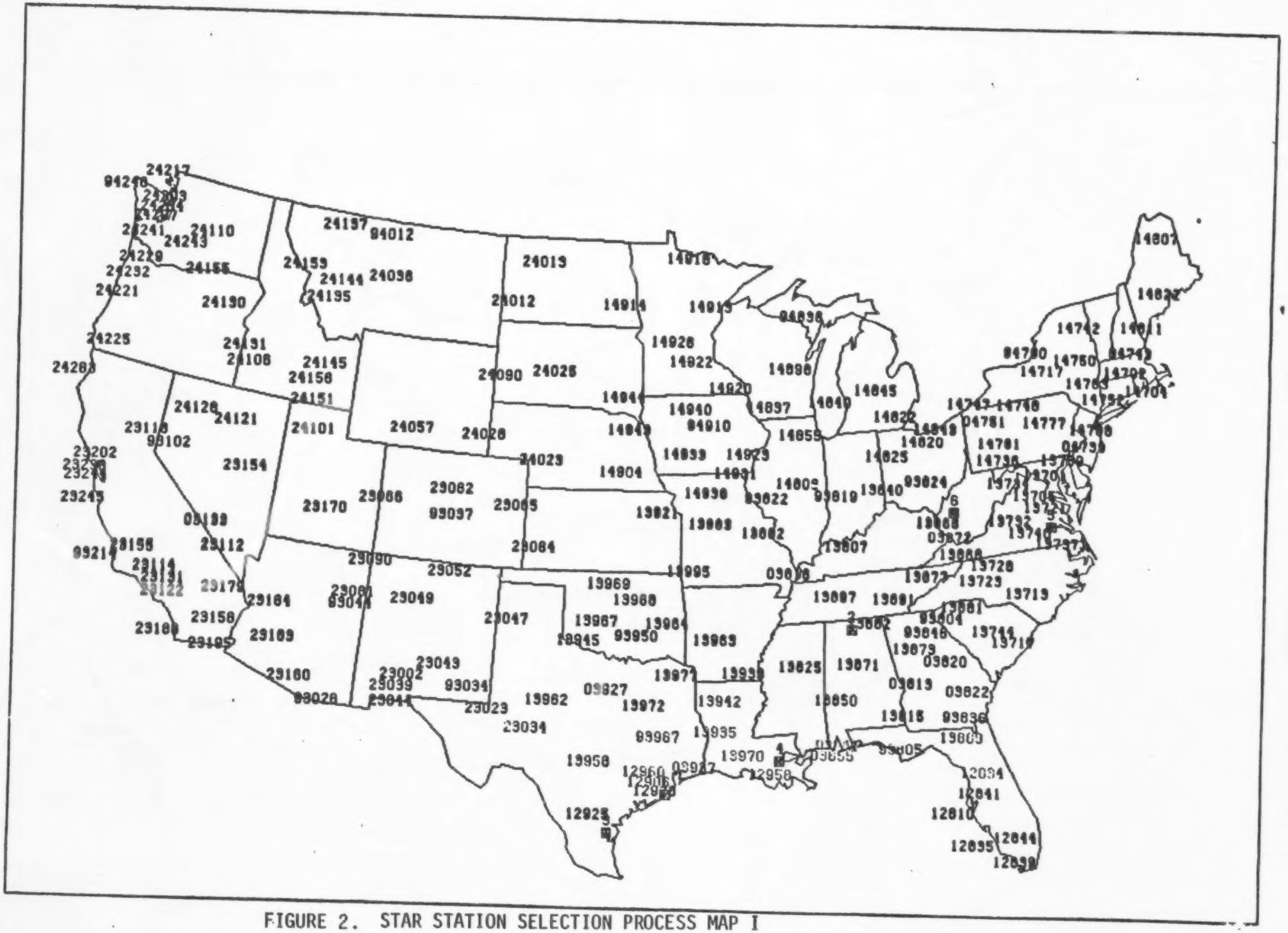

24217
94240
24241
24110
24243
24229
24232
24155
24221
24130
24225
24283
24131
24108
24157
94012
24159
24144
24038
24195
24145
24156
24151
24101
24013
24012
24090
24026
24057
24028
24023
24126
24121
23110
93102
23154
23202
23245
23170
23066
23062
93037
23065
23064
03133
23155
23112
23114
23122
23179
23184
23156
23180
23169
23160
23090
23049
23052
23047
23002
23039
93034
23023
23034
14918
14914
14913
14926
14922
14920
14898
14897
14840
14845
14940
94910
14844
14849
14839
14923
14855
14904
14936
13821
13983
13802
14820
14825
93024
13840
93819
93822
13995
13969
13968
13967
13984
93950
13945
13963
13962
03927
13972
93967
13958
13939
13942
13935
13970
12958
12960
12925
13807
03928
13897
13881
13877
13725
13728
13719
13825
13871
13850
93830
93820
93805
13889
12834
12841
12810
12844
12835
12839
14807
14742
14611
14750
14717
14701
14736
14777
94790
13713
13744

FIGURE 2. STAR STATION SELECTION PROCESS MAP I

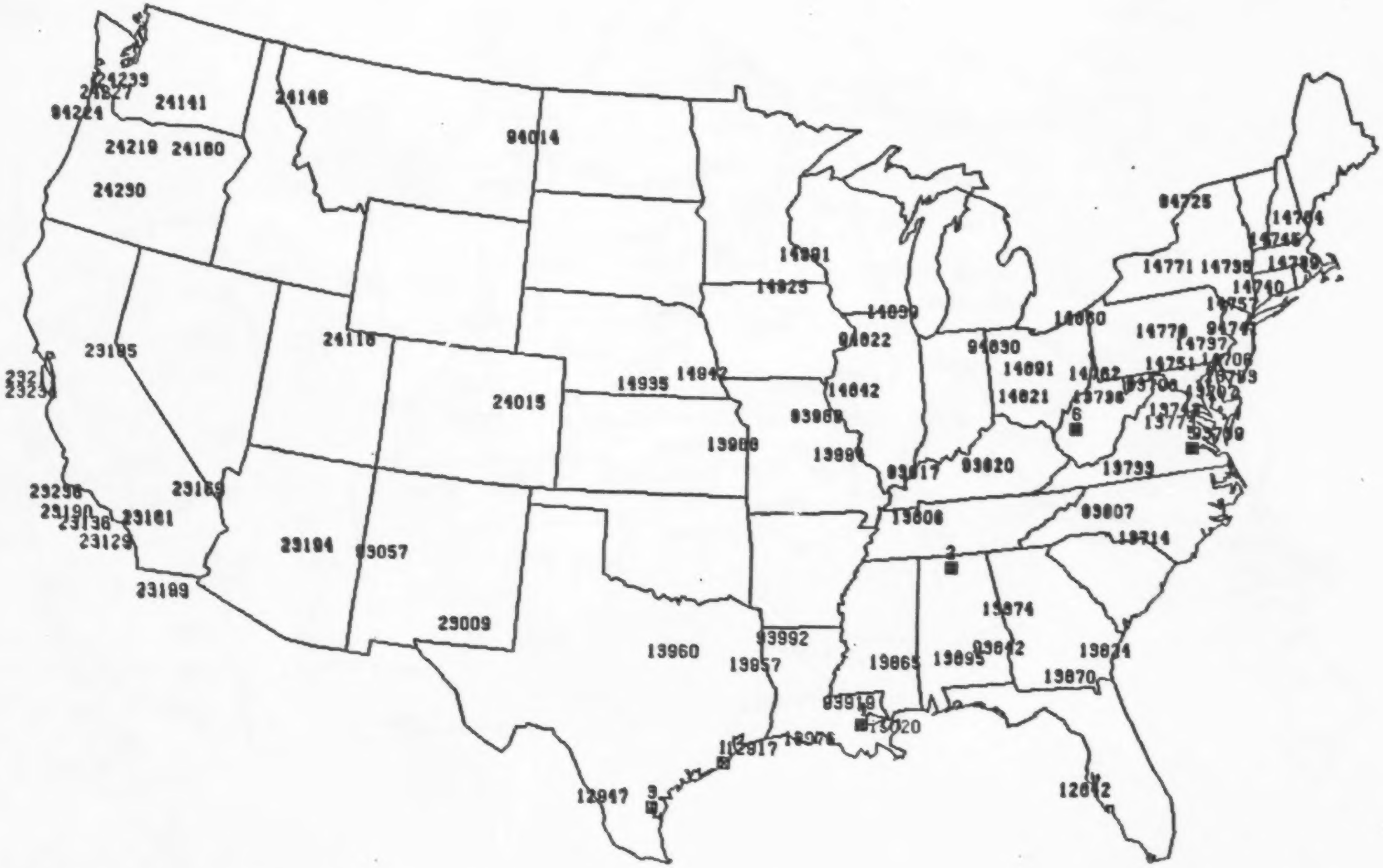

24239
24227
94224
24141
24148
24219
24180
24230
94014
24110
24015
23195
23230
23234
23169
23258
23190
23136
23129
23161
23189
23184
93057
29009
13960
12947
12917
93992
13957
14942
14935
13908
14991
14925
14839
94022
14842
93968
13889
93817
13808
93820
94830
14891
14821
14860
14862
13736
93706
14778
14797
14751
94725
14771
14735
14704
14745
14789
14740
14757
13743
13773
93799
13799
93807
13714
13974
93842
13895
13865
93919
13020
13976
13874
13870
12842
2
3
6

FIGURE 3. STAR STATION SELECTION PROCESS MAP II

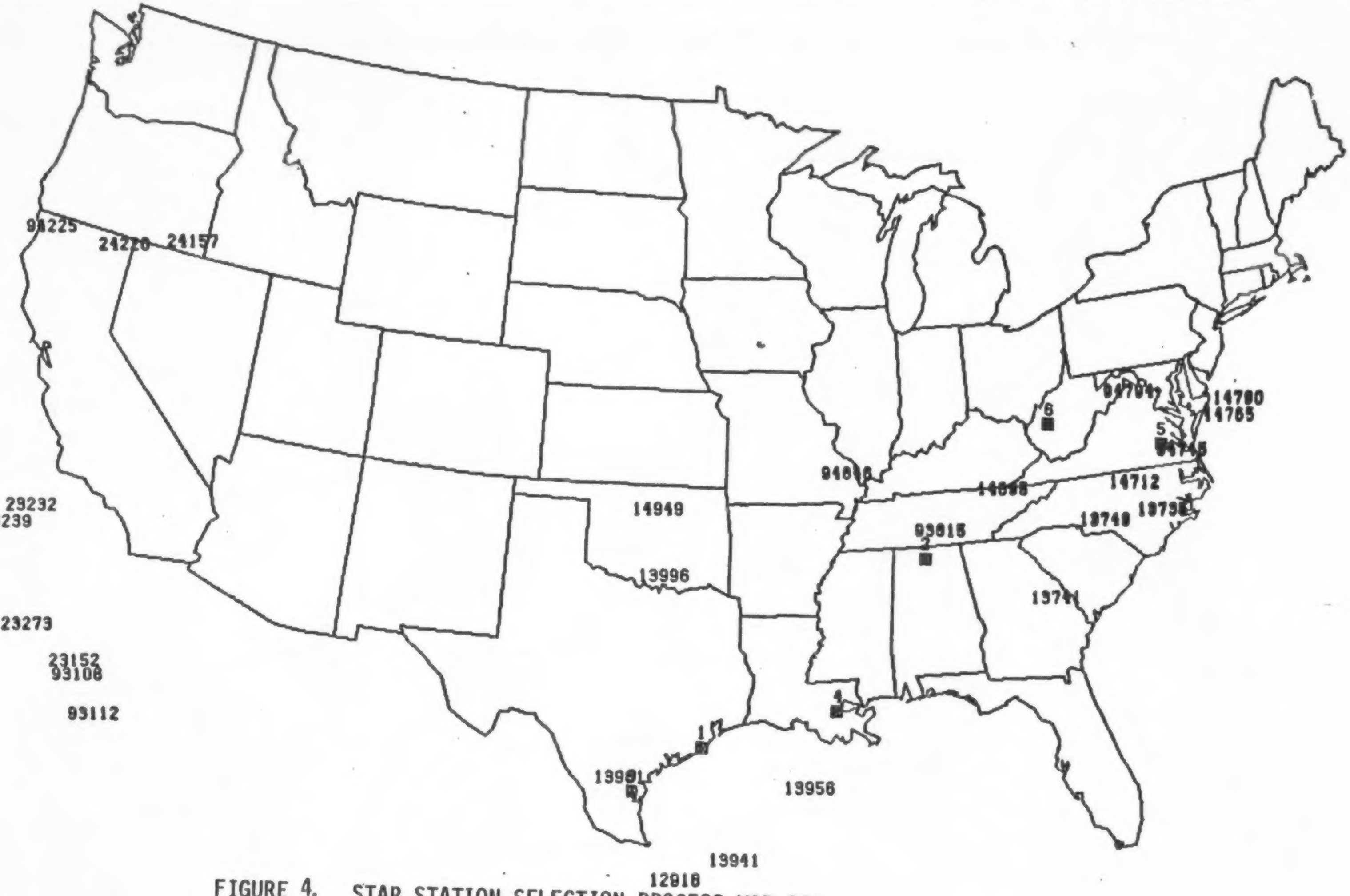
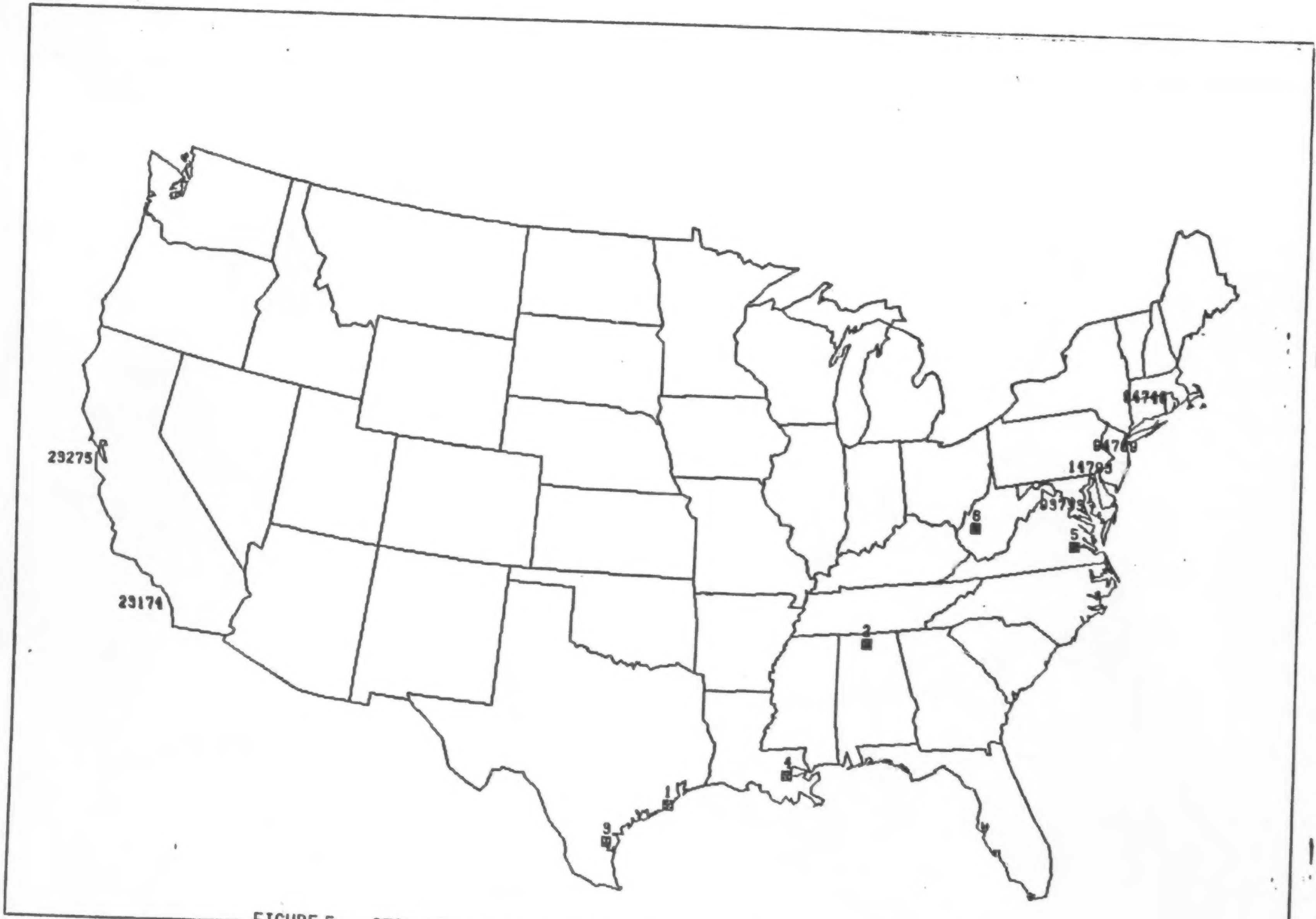

94225
24220
24157
23232
23239
23273
23152
93108
93112
14949
13996
13981
1
4
13958
13941
12918
94816
14898
93815
2
6
5
14712
13740
13741
14780
14765

FIGURE 4. STAR STATION SELECTION PROCESS MAP III



94746
94789
14795
93795
6
5
2
4
1
9
29275
23174

~~FIGURE 6. STAR STATION SELECTION PROCESS MAP IV~~

WBAN STATIØNS

SECTION 3

EXPOSURE-DOSAGE ESTIMATION APPROACH

As discussed in Section 1, the emissions sources were treated in terms of three main categories:

> Major point sources, individually specified.

> General point sources represented categorically by a prototype.

> Area source representations of numerous, widely distributed, minor sources.

This section explains the exposure-dosage estimation approach for each of those categories.

MAJOR (SPECIFIC) POINT SOURCES

Major sources of most of the selected chemicals were specifically identified manufacturing plants. Concentration patterns caused by unit emissions from such sources depend most strongly on three factors:

> Source elevation above terrain; effective plume elevation may, in turn, depend on meteorological factors.

> Wind vectors (speed and direction).

> Dispersive effects (intensity of atmospheric turbulence).

For the present study a Gaussian model in the climatological form of the EPA's CDM, using the same basic dispersion algorithm, was coded and used to estimate the annual average ground-level concentrations resulting from emissions from major point sources. It was necessary to plan for executing the model for up to 1000 major point sources and generic point sources, but much of the computer time required by comparable existing algorithms is used for repetitive evaluations of the Gaussian kernel. Because wind velocity and atmospheric stability are the only meteorological variables involved in the Gaussian dispersion estimation, the Gaussian kernel needs to be evaluated only 36 times (6 wind speeds times 6 stability classes) for a specific combination of source elevation and building cross-section. The Gaussian algorithms can be used to generate a file of normalized Gaussian solutions (concentration/emissions), one for each combination of wind speed and stability, so we computed and stored these Guassian concentration files for use in conjunction with STAR data, emissions data, and reactivity data, in estimating the annual average concentrations. Substantial computer savings were achieved through this "matrix modeling" approach.

In SAI's matrix modeling concept, the climatological Gaussian algorithm would be used to generate a file of normalized Gaussian solutions, one for each combination of wind speed and stability. This task is accomplished through evaluation of the function given by:

$$\left[\frac{\chi}{Q}(R)\right]_{ij} = \frac{\chi}{Q}(R, U_i, S_j) \quad , \qquad (1)$$

where

χ = concentration,
Q = emissions rate,
U_i = i-th wind speed
S_j = j-th stability class,
R = travel distance from the source.

For reactive materials, this equation is extended to include a dependence on an exponential decay rate derived from prototype analysis:

$$\left[\frac{\chi}{Q}(R)\right]_{ijk} = \frac{\chi}{Q}(R,U_i,S_j,\tau_k) \quad . \qquad (2)$$

where τ_k is the half-life of the k-th species. With this computer file available, climatological concentration patterns are obtained by matrix multiplication with STAR* data:

$$\left[\frac{\chi}{Q}(R,\theta)\right]_k = \left[\frac{\chi}{Q}(R)\right]_{ijk} \phi(U_i,S_j,\theta) \quad . \qquad (3)$$

The maximum radius considered in the exposure/dosage estimation was set as 20 km for major point sources. Concentrations were estimated for 10 receptors--0.2, 0.3, 0.5, 0.7, 1.0, 2.0, 5.0, 10.0, 15.0, and 20.0 km from the source--along each of the 16 wind directions. As shown in Table 13 for the example of chloroprene, there may be instances of more than one type of point source (each with its characteristic release height, emissions rate, etc.) within a single plant. For the case shown, fugitive emissions (valve and flange leaks, etc.) that are random and indeterminate but not negligible are approximated by a single source point 5 m above the ground. This is a height typical of outdoor plumbing. The building wake effect assures that the assumed point source is represented as a source with dimensions larger than the adjacent structure. Each emissions category was modeled individually, and the total ground-level concentrations resulting from plant emissions were then computed by summing the individual estimates.

---

* STAR data are standard climatological frequency of occurrence summaries formatted for use in EPA models and available for major U.S. sites from the National Climatic Center, Asheville, North Carolina. The data consist of frequencies ϕ, tabulated as functions of wind speed, U_i; stability, S_j; and direction, θ.

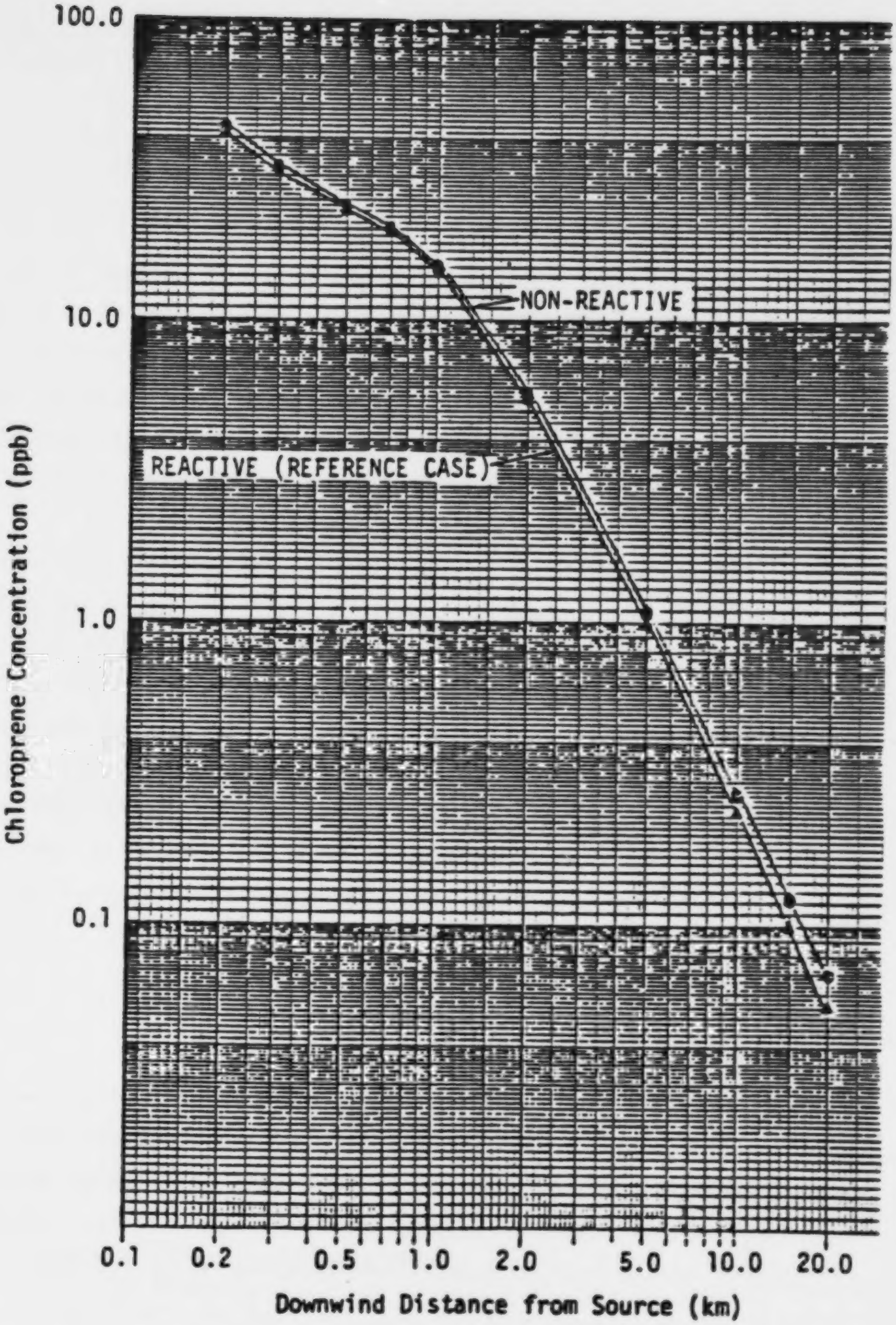
The dispersion algorithm can also treat chemical formation and decay, enhanced dispersion caused by building wake effects, and release or stack height. These features are discussed in the following subsections.

Chemical Reactivity

The detailed approach adopted in estimating the effect of chemical reactions on ambient concentrations is shown with chloroprene as an example. Chloroprene is an organic compound that is decidedly photoreactive in the atmosphere. Based on preliminary calculations conducted with estimated decay rate, approximately 90 percent of the chloroprene emitted into the sunlit urban atmosphere would be removed within an hour through reaction with hydroxyl radicals and ozone molecules. However, the chemical decay rates are much lower in the nighttime or under overcast conditions. Figure 6 displays a comparison between the resulting concentrations along a single wind direction with and without the chemical decay computed for a chloroprene example.* Because the chemical reactions that change atmospheric concentrations occur over time, the chemical reactivity of a compound has less impact on the concentrations near the emissions source than further downwind. The difference in concentrations between

---

* The data inputs that are necessary for the reactive case include: the chloroprene emissions source location (the Dupont plant at Laplace, Louisiana); the nature of the source emissions (process vent); the map coordinates (90°32'00"W, 30°04'0"N); the stack height (20 m); the effective building cross section (100 m^2); the emissions rate (34.23 g/sec); the daytime decay rate (0.00058 sec^{-1}); the nighttime decay rate (0.000020 sec^{-1}); the wind direction (1, from the north); and the STAR station [12916 (New Orleans Muisant)].



Source: Systems Applications, Incorporated computations using SAI dispersion model and SAI reactivity estimates.

FIGURE 6. EFFECTS OF CHEMICAL REACTIVITY ON CONCENTRATION DISTRIBUTION OF CHLOROPRENE

the two curves of Figure 6 at 200 meters from the source is about 3 percent (43.2/41.9 - 1); at 20 km from the source the difference is about 30 percent (0.070/0.054 - 1).

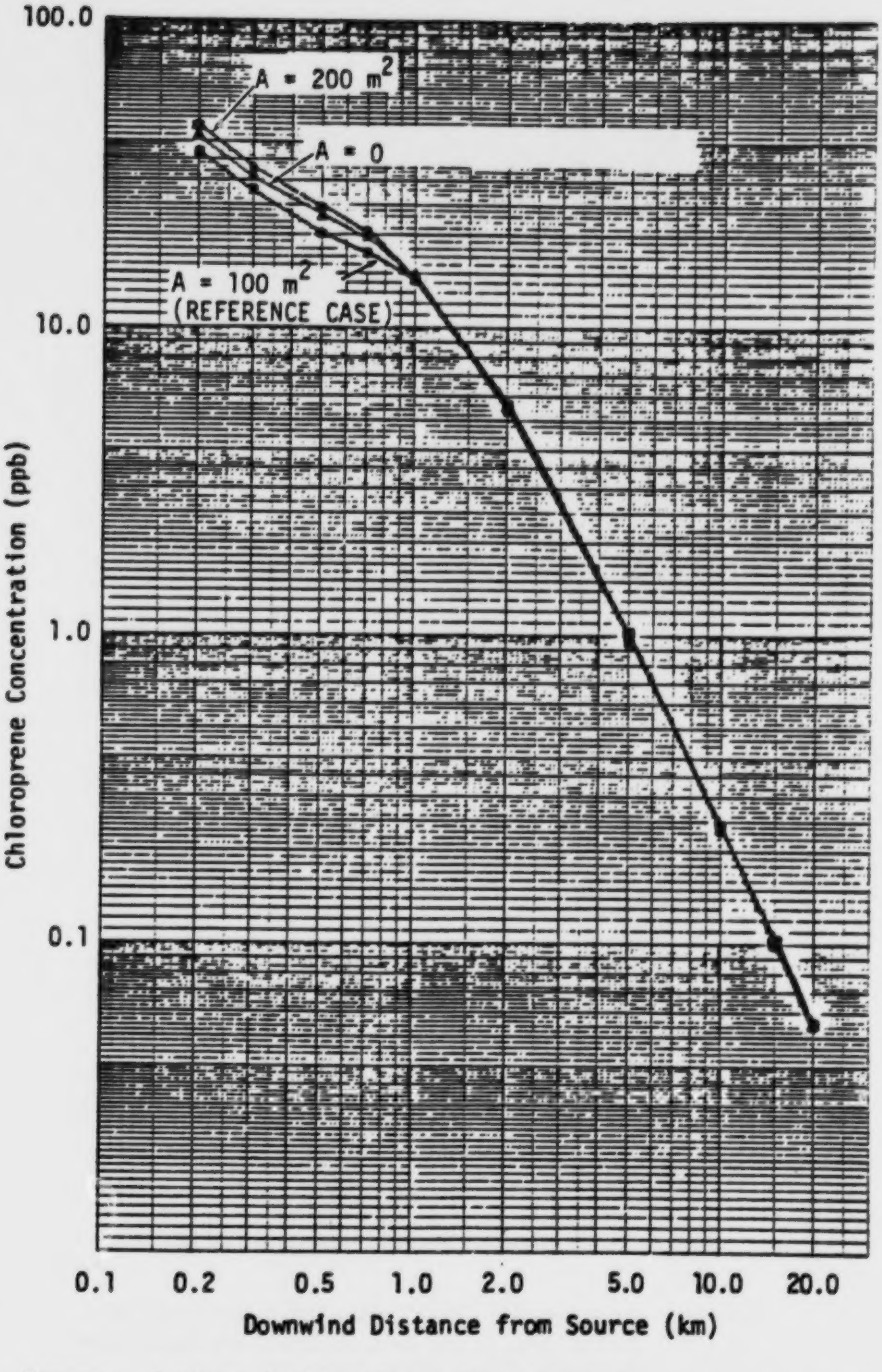
Building Wake Effect

Pollutants emitted into the wake of a building are subject to an enhanced dispersion (i.e., the concentration is reduced very quickly by the turbulence on the lee side of the building). If a dispersion analysis ignored this effect, the occurrence of high concentrations would be overestimated. A detailed description of the equations used in estimating the building wake effect is addressed in the section beginning on page 99.

The ground-level concentrations that result from different building structure dimensions are depicted in Figure 7, where the major parameters for estimating these concentrations are the same as those of the reference case. Clearly, the building wake effect would have insignificant impacts on ground-level concentrations at points further downwind from the source than 1.0 km. However, sources with larger building effects would result in larger ground-level concentrations near the sources. Additional analyses that assess the precise impacts of building wake effect may be required to determine the extent to which the example in Figure 8 is site-specific.

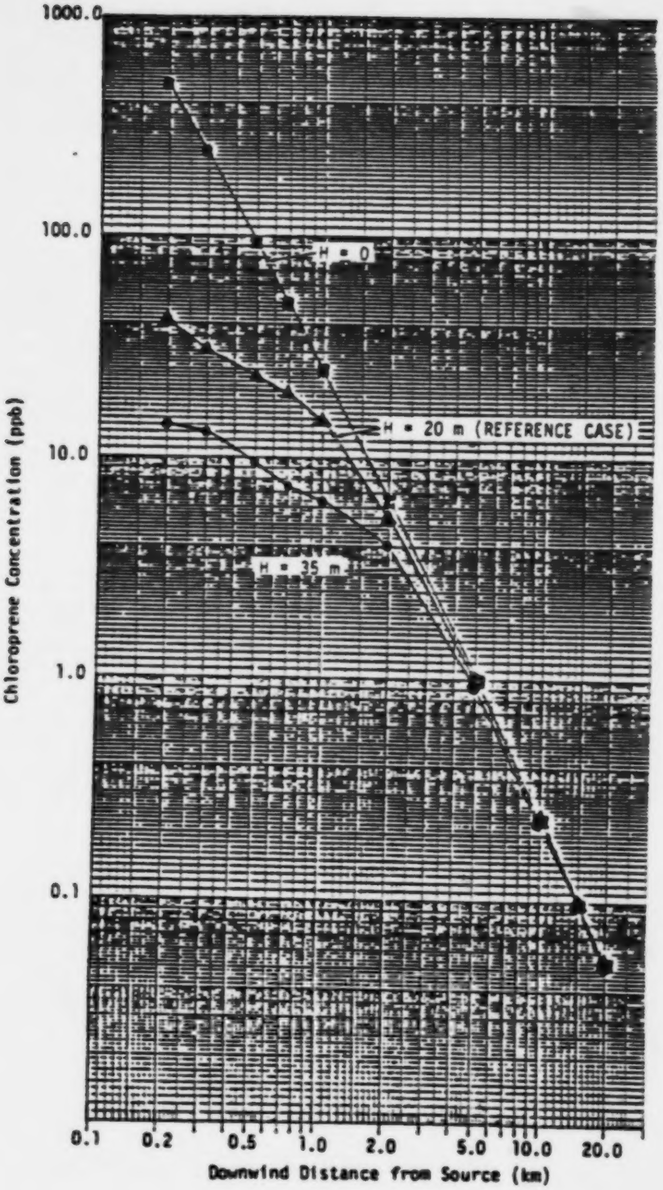
Release Height

The exact release height of a source can have a great effect on ground-level concentrations. As Figure 8 shows, concentrations resulting from ground-level emissions ($H = 0$) can be more than 10 times as great as those resulting from emissions at a moderate height ($H > 20$ m). However, these differences become insignificant further downwind ($R > 5$ km).



Source: Systems Applications, Incorporated computations using SAI dispersion model and SAI building wake algorithms.

FIGURE 7. EFFECT OF BUILDING WAKE ON CONCENTRATION DISTRIBUTION OF CHLOROPRENE



Source: Systems Applications, Incorporated computations using SAI dispersion model and Briggs' plume rise formulas

FIGURE 8. IMPACTS OF RELEASE HEIGHT ON CONCENTRATION DISTRIBUTION OF CHLOROPRENE

The evidence from Figures 6, 7, and 8 indicates that ground-level concentrations decrease approximately log-log linearly with distance at receptors more than 2 km distant from the source. Apparently, a plot of this log-log linear relationship could be used to interpolate concentrations at specific locations within the range of 2 to 20 km from the source.

The Point Source Algorithm

The annual average concentration pattern of a given chemical compound downwind from an emissions source is estimated by using the climatological form of the Gaussian algorithm (Turner, 1970) that is given by the detailed equation used to prepare the computer program:

$$\chi(R,\theta,H,\tau_k) = 2.03Q \sum_i \sum_j \frac{\mathrm{STAR}(\theta,S_j,N_i)\,\mathrm{EXP}(R,S_j,H)}{U(N_i)\; R\sigma_z(R,S_j)} \cdot \mathrm{DEC}(R,S_j,N_i,\tau_k) \qquad (4)$$

where the symbols have the following meanings:

Polar Coordinates

R = Distance (meters) from the source to the receptor,

θ = Compass azimuth of the radius, R; also wind azimuth.

Atmospheric Parameters

u = wind speed (meters/second),

θ = wind azimuth (i.e. direction from which wind is blowing),

σ_z = vertical dispersion coefficient $\left(\frac{\text{meter}}{\text{second}}\right)^2$,

N_i = the i-th wind speed category,

S_k = the k-th dispersion (stability) category.

Functions

STAR = The STability ARray* of joint probabilities of occurrence of wind speed, direction and stability combinations,

EXP = Gaussian dispersion function for elevated pollutant plume.

DEC = Decay function characterizing loss of chemical species, k, due to atmospheric chemical reactions.

Emission Parameters

Q = Emissions rate (grams/second),

H = Effective plume height (meters).

Species Parameter

τ_k = Decay rate of species k due to atmospheric chemical reaction.

Grid System

A polar grid array of sectors of uniformly increasing size radially outward from the source was used to overlay the region of interest. Concentration is calculated at the four corners of each sector. Another use of the grid system is to catalog population data for exposure/dosage calculations.

Climatological Parameters

The STAR data were obtained from the National Climatic Center (Asheville, North Carolina). As received they were not in a uniform for-

---

[*] Site-specific, from data from several hundred sites in U.S.

mat with respect to the stability used. Data from some stations was in the original STAR format with up to eight stability classes. Data from other stations had been modified so as to distinguish between day and nighttime occurrences of neutral D stability. After receipt from the NCC, all unmodified data sets were modified according to the present EPA day-night system (Busse and Zimmerman, 1973), as shown in Table 12. This splitting of the neutral stability data is especially important when other processes, such as chemical reactions, have diurnal variations.

For all the point source analyses, neutral (D) stability events designated by the regular STAR data are divided into two classes: 40 percent of the neutrally stable hours are assumed to occur at night, and the remaining 60 percent in the daytime (Burt, 1977).

Since the lower portion of the atmosphere over urban areas is usually unstable, even when the adjacent rural area is stable, neutral stability is assumed for point sources analyses in urban areas whenever the STAR algorithm indicates stable conditions (Classes E and F). This procedure follows the recommendations of the EPA.

TABLE 12. PASQUILL-GIFFORD STABILITY CLASSES USED IN POINT SOURCE ANALYSES

Pasquill/Gifford Stability Classes	Urban Areas	Rural Areas
A	A	A
B	B	B
C	C	C
D	D-day	D-day
E	D-night	D-night
E	D-night	E
F	D-night	F

Source: Busse and Zimmerman (1973).

Wind Speed

The wind speed $U(N_i)$ for each wind speed class is taken as the average wind speed of the range for the given class (Busse and Zimmerman, 1973).

Vertical Variation of Wind Speed

Generally, the wind speed at plume height will differ from the measured wind speed at the anemometer height of 10 meters. To account for this vertical variation, a power law wind profile in the form

$$U(H) = U_{10} \left(\frac{H}{10} \right)^{P} \qquad (5)$$

was used, as recommended by Turner (1970). The exponent p, as presented in EPA (1977), is listed for each stability class:

Pasquill/Gifford Stability Classes	P
A	0.10
B	0.15
C	0.20
D	0.25
E	0.30
F	0.30

Plume Height

The height of the plume centerline, he, is the sum of the physical stack height, hs, and the plume rise, Δh:

$$he = hs + \Delta h \quad . \qquad (6)$$

In this analysis, plume rise is determined using Briggs's equations (1969, 1970, 1975) for momentum plumes and buoyancy plumes from low level emissions sources as recommended by Turner and Novak (1978).

Vertical Dispersion Function

The value of σ_z where emissions do not suffer from downwash phenomena is calculated from formulas recommended by Briggs (1973), where R is the downwind distance in meters:

Pasquill Stability Class	σ_z (m)
A	$0.20\ R$
B	$0.12\ R$
C	$0.08\ R\ (1. + 0.0002\ R)^{-1/2}$
D(day and night)	$0.06\ R\ (1. + 0.0015\ R)^{-1/2}$
E	$0.03\ R\ (1. + 0.0003\ R)^{-1}$
F	$0.16\ R\ (1. + 0.0003\ R)^{-1}$

The proposed formulas for σ_z for emissions that are influenced by building wakes are:

Pasquill Stability Class	σ_z (m)
A	$0.20 (R + \Delta R)$
B	$0.12 (R + \Delta R)$
C	$0.08 (R + \Delta R)[1. + 0.0002 (R + \Delta R)]^{-1/2}$
D	$0.06 (R + \Delta R)[1. + 0.0015 (R + \Delta R)]^{-1/2}$
E	$0.03 (R + \Delta R)[1.0.0003 (R + \Delta R)]^{-1}$
F	$0.16 (R + \Delta R)[1. + 0.0003 (R + \Delta R)]^{-1}$

where ΔR is the displacement distance and is calculated using:

Pasquill Stability Class	ΔR (m)
A	$1.95 A^{0.5}$
B	$2.72 A^{0.5}$
C	$4.09 A^{0.5}$
D	$4.95 A^{0.5}$
E	$9.03 A^{0.52}$
F	$14.88 A^{0.52}$

Chemical Decay

The four-class scheme for photochemical decay categorization is adopted in the dispersion models. The default values of reaction rate constants for each class are listed below:

Time of Day	Class I Very Reactive	Class II Reactive	Class III Moderately Reactive	Class IV Unreactive
Daytime	1.0×10^{-2}	5.0×10^{-3}	5.0×10^{-4}	0
Nighttime	5.0×10^{-5}	5.0×10^{-5}	0	0

Source: Systems Applications, Incorporated, review as described in Section 2, pp. 55 ff.

Matrix Modeling Technique

To save computing time, the Gaussian algorithm [2.03 $EXP(R,S_j,H)/\delta_z(R,S_j)$] and the decay function ($\exp[-\tau_K(S_j)R/U(N_i)]$) from Eq. (4) are used to generate files of normalized Gaussian solutions--one for each combination of six wind speed categories, seven stability classes, and four chemical reactivity groups. For each of the combinations, 10 different downwind distances R, 16 wind directions θ, and 5 different effective stack heights are used. The values chosen for the 10 different downwind distances are 0.2, 0.3, 0.5, 0.7, 1.0, 2.0, 5.0, 10.0, 15.0, and 20.0 kilometers. The values for the wind speeds are 1.50, 2.46, 4.47, 6.93, 9.61, and 12.52 m/sec. The values chosen for the effective stack height are 0.0, 5.0, 10.5, 20.0, and 35.0 meters.

Sector Averaging

The constant 2.03 of Eq. (4) is the product of the factors $2/(\sqrt{2\pi}\ 2\pi/16)$. This is obtained from the bivariate Gaussian sector averaging form for a 22.5° (i.e., 2π/16) sector. This results in a uniform concentration across the wind sector at a given distance and height.

Operation

MATRIX and GAUSS are the two major computer programs used in major point source analysis. The function of program MATRIX is to generate a matrix file containing dispersion functions as a function of wind direction and radial distance from the source for a single point source with a chosen physical characteristic. The GAUSS program reads the matrix data file generated by MATRIX and calculates the ground concentration pattern carried by the sources defined in the source definition data set. Output from GAUSS is a data file that contains surface concentration values.

There is no input data requirement to run the MATRIX program. However, GAUSS does require input. In addition to the intermediate data file created by MATRIX, GAUSS requires an input data set that identifies the locations and characteristics of the sources as well as the surrounding meteorological and climatological conditions. Sequences of input data cards are shown in Table 13.

Vertical Dispersion Function for Downwash Phenomena

When the pollutants are emitted from a vent or opening on a building, or when the exit velocity of gases emitted from a stack is less than 1.5 times the mean wind speed, dispersion of pollutants is determined by the atmospheric dispersion mechanism and the building-induced turbulence.

Following Briggs (1975), the atmospheric dispersion function for $\sigma_y(x)$, m, and $\sigma_z(x)$ can be expressed as follows (open country conditions, $10^2 < x < 10^4$m):

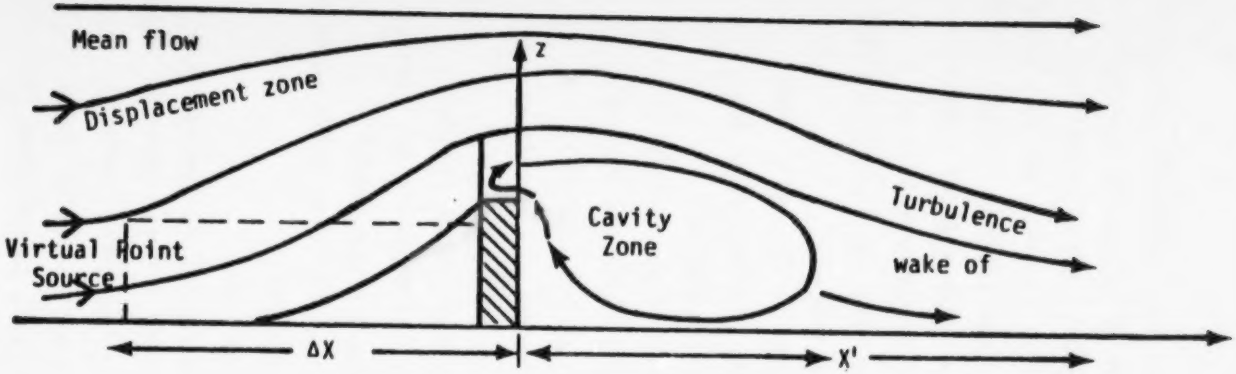
Pasquill Type	$\sigma_y(m)$	$\sigma_z(m)$
A	$.22x(1 + .001x)^{-1/2}$	$.20x$
B	$.16x(1 + .0001x)^{-1/2}$	$.12x$
C	$.11x(1 + .0001x)^{-1/2}$	$.08x(1 + .0002x)^{-1/2}$
D	$.08x(1 + .0001x)^{-1/2}$	$.06x(1 + .0015x)^{-1/2}$
E	$.06x(1 + .0001x)^{-1/2}$	$.03x(1 + .0003x)^{-1}$
F	$.04x(1 + .0001x)^{-1/2}$	$.016x(1 + .0003x)^{-1}$

Estimation of the additional initial dispersion in the building wake is based on Holland's virtual point source concept. In this concept, dispersion is as if the emissions came from a virtual source, farther upwind than the real one and diffused by Gaussian processes to a plume as wide as the building wake. The downwind distance x can be expressed as $x' + \underline{\Delta x}$, where x' is the distance between the receptor and the actual emission source, while $\underline{\Delta x}$ is the distance between the actual point source and virtual point source (see Figure 9). The total dispersion factor can be expressed as:

TABLE 13. SEQUENCE OF INPUT DATA CARDS FOR PROGRAM GAUSS

Card No.	Variables	Format	Contents
1	NEMS	I10	Number of emissions sources
2	LINE	7A5	Emissions source identifier
	LAT	I6	Latitude (degree, minute, second)
	LONG	I7	Longitude (degree, minute, second)
	ISTAR	I5	Chosen STAR station number
	T	F5.0	Ambient temperature (°K)
	ALAPSE	2F5.0	Lapse rate for stability class E, F
	IURB	I1	Urban index IURB = 1 for rural area IURB = 0 for urban area
3	IUSE	I5	User identifier
	NOS	I2	Number of source type within each emissions source
	ISPEC	A10	Name of the chemical
	ICSPEC	A10	Compounds
4	IEMTYP	ZX,A1	Emissions index
	Q	F12.0	Emissions rates (lbs/hr)
	STAK	F4.0	Physical stack height (meters above ground level)
	XA	F4.0	Typical building cross sectional area (meters^2)
	IVENT	I1	Stack index IVGNT = 1 for nonvertical stack IVGNT = 0 for vertical stack
	D	F4.0	Stack diameter (meters)
	VS	F5.0	Gas exit velocity (m/s)
	TS	F4.0	Gas exit temperature (°K)

Note: GAUSS also requires the SAI-modified STAR data file.


Mean flow
Displacement zone
z
Virtual Point Source
Cavity Zone
Turbulence
wake of
ΔX
X'

Q = Emission source strength

ΔX = Distance between the virtual point source and the actual point source as a result of the building of displacement zone

FIGURE 9. SCHEMATIC ILLUSTRATION OF VIRTUAL POINT SOURCE CONCEPT

Pasquill Type	σ_y (m)
A	$.22\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$
B	$.16\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$
C	$.11\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$
D	$.08\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$
E	$.06\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$
F	$.04\ (x' + \Delta x)\ (1 + 0.0001\ (x' + \Delta x)^{-1/2}$

Pasquill Type	σ_z (m)	
A	$0.20\ (x' + \Delta x)$	(6a)
B	$0.12\ (x' + \Delta x)$	(6b)
C	$0.08\ (x' + \Delta x)\ (1 + .0002\ (x' + \Delta x)^{-1/2}$	(6c)
D	$0.06\ (x' + \Delta x)\ (1 + .0015\ (x' + \Delta x)^{-1/2}$	(6d)
E	$0.03\ (x' + \Delta x)\ (1 + .0003\ (x' + \Delta x)^{-1/2}$	(6e)
F	$0.016\ (x' + \Delta x)\ (1 + .0003\ (x' + \Delta x)^{-1/2}$	(6f)

For $\underline{x}'$=o, the building-induced turbulence is the only mechanism that controls the dispersion of pollutants. Therefore, the total dispersion function here can be expressed as:

σ_y (m)	σ_z (m)	
$.22\ (\Delta x)\ (1 + 0.0001\Delta x)^{-1/2}$	$0.20\ (\Delta x)$	(7a)
$.16\ (\Delta x)\ (1 + 0.0001\Delta x)^{-1/2}$	$0.12\ (\Delta x)$	(7b)
$.11\ (\Delta x)\ (1 + 0.0001\Delta x)^{-1/2}$	$0.08\ (\Delta x)\ (1 + 0.0002\Delta x)^{-1/2}$	(7c)
$.08\ (\Delta x)\ (1 + 0.0001\Delta x)^{-1/2}$	$0.06\ (\Delta x)\ (1 + 0.00015\Delta x)^{-1/2}$	(7d)
$.06\ (\Delta x)\ (1 + 0.0001\Delta x)^{-1/2}$	$0.03\ (\Delta x)\ (1 + .0003\Delta x)^{-1}$	(7e)
$.04\ (\Delta x)\ (1 + 0.0001Wx)^{-1/2}$	$0.016\ (\Delta x)\ (1 + .0003\Delta x)^{-1}$	(7f)

The product of σ_y and σ_z is:

$$\sigma_y \, \sigma_z \, (m^2) =$$

$$4.4 \times 10^{-2} \, (\Delta x)^2 \, [1 + 10^{-4} \, (\Delta x)]^{-1/2} \qquad (8a)$$

$$1.9 \times 10^{-2} \, (\Delta x)^2 \, [1 + 10^{-4} \, (\Delta x)]^{-1/2} \qquad (8b)$$

$$8.8 \times 10^{-3} \, (\Delta x)^2 \, [1 + 3. \times 10^{-4} \, (\Delta x) + 2 \times 10^{-8} \, (\Delta x)^2 \,]^{-1/2} \qquad (8c)$$

$$4.8 \times 10^{-3} \, (\Delta x)^2 \, [1 + 1.6 \times 1^{-3} \, (\Delta x) + 1.5 \times 10^{-7} \, (\Delta x)^2]^{-1/2} \qquad (8d)$$

$$1.8 \times 10^{-3} \, (\Delta x)^2 \;\; 1 + 7.0 \times 10^{-4} \, (\Delta x) + 1.5 \times 10^{-7} \, (\Delta x)^2 + 9. \times 10^{-12} \, (\Delta x)^2 \; {-1/2} \qquad (8e)$$

$$6.4 \times 10^{-4} \, (\Delta x)^2 \;\; 1 + 7.0 \times 10^{-4} \, (\Delta x) + 1.5 \times 10^{-7} \, (\Delta x)^2 + 9. \times 10^{-12} \, (\Delta x)^2 \; {-1/2} \qquad (8f)$$

Gifford (1968) identified the total diffusion factor as:

$$\sigma_y = (\sigma_y{}^2 + CA/\pi)^{1/2} \quad ,$$

where A is building cross sectional area perpendicular to the mean wind and C is the building factor.* It is found that $0.5 < C < 2.0$. At $X'=0$, the total dispersion function becomes

$$\sigma_y = (CA/\pi)^{1/2} \quad ,$$

$$\sigma_z = (CA/\pi)^{1/2} \quad ,$$

Multiply σ_y and σ_z to obtain:

---

* Dependence on the height/width ratio of a building was not included. There is great variety in the sizes and shapes of buildings associated with the variety of emissions sources. Generally, the structures were complex, there was uncertainty as to how well this correction should be detailed, and it was difficult to obtain relevant data.

$$\sigma_y \sigma_z = CA/\pi \quad . \qquad (9)$$

Let C = 0.5 (a conservative estimation), and compare Eqs. (8a), (8b), (8c), (8d), (8e), and (8f) with Eq. (9); one gets:

Pasquill Stability	$\sigma_y\ \sigma_z\ (m^2) = \frac{CA}{\pi}$	
A	$4.4 \times 10^{-2}\ (\Delta x)^2\ [1 + 10^{-4}\ (\Delta x)]^{-1/2}$	(10a)
B	$1.9 \times 10^{-2}\ (\Delta x)^2\ [1 + 10^{-4}\ (\Delta x)]^{-1/2}$	(10b)
C	$8.8 \times 10^{-3}\ (\Delta x)^2\ [1 + 3. \times 10^{-4}\ (\Delta x)$	
	$+ 2 \times 10^{-8}\ (\Delta x)^2\ ]^{-1/2}$	(10c)
D	$4.8 \times 10^{-3}\ (\Delta x)^2\ [1 + 1.6 \times 1^{-3}\ (\Delta x)$	
	$+ 1.5 \times 10^{-7}\ (\Delta x)^2]^{-1/2}$	(10d)
E	$1.8 \times 10^{-3}\ (\Delta x)^2\ \ 1 + 7.0 \times 10^{-4}\ (\Delta x) + 1.5 \times 10^{-7}\ (\Delta x)$	
	$+ 9. \times 10^{-12}\ (\Delta x)^2\ {-1/2}$	(10e)
F	$6.4 \times 10^{-4}\ (\Delta x)^2\ \ 1 + 7.0 \times 10^{-4}\ (\Delta x) + 1.5 \times 10^{-7}\ (\Delta x)^2$	
	$+ 9. \times 10^{-12}\ (\Delta x)^2\ {-1/2}$	(10f)

Eqs. (10a) through (10f) are then solved numerically, and the Δx can be expressed as:

Pasquill Stability	Δx
A	$1.95A^{0.5}$
B	$2.72A^{0.5}$
C	$4.05A^{0.5}$
D	$4.95A^{0.5}e^{A} \times 10^{-6}$
E	$9.03A^{0.52}e^{3.6A} \times 10^{-6}$
F	$14.88A^{0.52}e^{A} \times 10^{-5}$

By substituting them into Eqs. (6a) through (6f), one can obtain the total dispersion function.

Exposure and Dosage Estimation Scheme

SAI has coded this "matrix" dispersion modeling approach into a standard Fortran program. The output of the program is a well-formatted concentration array for 160 receptors around the plant (10 receptors along each of the 16 wind directions). These are the sum of concentration patterns resulting from all sources within a plant. A typical concentration pattern printout is shown in Table 14, and the chloroprene-emitting Denka plant at Houston is used here as an example. This subsection delineates the basic approach used in combining the concentration pattern with the population distribution pattern around a plant. Two terms are defined here and are used frequently in the following discussion. A polar grid point is one of the 160 receptors at which concentrations were estimated by the dispersion modeling. A population centroid is the population-weighted geographical center of an ED/BG for which geodetic coordinates are known.

A two-level scheme was adopted to pair up concentrations and populations prior to the computation of dosages and exposures. The two-level approach is appropriate because the concentrations are defined on a radius-azimuth (polar) grid pattern with non-uniform spacing. At small radii the grid cells are much smaller than ED/BGs; at large radii the grid cells are much larger than ED/BGs. To form the product of population times concentration, both factors at the same set of points are required. Interpolation techniques to accomplish this are most appropriately applied by interpolating values of the factor defined on the coarse network at the locations of the finer grid, thus maximizing the resolution and minimizing the uncertainties of interpolation. Because the fine/coarse relationship varies with radius, the two-level approach is used.

For ED/BG centroids located between 0.1 km and 2.8 km from the source, populations were apportioned among neighboring concentration grid

TABLE 14. ANNUAL AVERAGE CHLOROPRENE CONCENTRATION DISTRIBUTION PATTERN IN THE VICINITY OF THE DENKA PLANT IN HOUSTON, TEXAS. Concentrations are in units of μg/m³.

Wind Direction	Downwind Distance (km)									
	.2	.3	.5	.7	1.0	2.0	5.0	10	15	20
1	2.6066E 01	1.6738E 01	9.1317E 00	3.0343E 00	3.4903E 00	1.2023E 00	2.7920E-01	9.0347E-02	4.6033E-02	2.8334E-02
2	1.7233E 01	1.0633E 01	3.7903E 00	3.7088E 00	2.2181E 00	7.6191E-01	1.7621E-01	3.6727E-02	2.1000E-02	1.7670E-02
3	1.6022E 01	1.0370E 01	3.3931E 00	3.3603E 00	2.1173E 00	7.2140E-01	1.6333E-01	5.2979E-02	2.6703E-02	1.6303E-02
4	1.3319E 01	8.2970E 00	4.4144E 00	2.7036E 00	1.6432E 00	3.3319E-01	1.2614E-01	4.0033E-02	2.0140E-02	1.2261E-02
5	2.2322E 01	1.3017E 01	7.2091E 00	4.3660E 00	2.6816E 00	8.9999E-01	2.0301E-01	6.4743E-02	3.2373E-02	1.9839E-02
6	2.0104E 01	1.2437E 01	6.3733E 00	4.1239E 00	2.4243E 00	8.1300E-01	1.8147E-01	3.9201E-02	2.9900E-02	1.8269E-02
7	2.3066E 01	1.3010E 01	8.3006E 00	3.4894E 00	3.2000E 00	1.1249E 00	2.3964E-01	8.3472E-02	4.2331E-02	2.3910E-02
8	3.2709E 01	2.0223E 01	1.1038E 01	7.0732E 00	4.2346E 00	1.4373E 00	3.3022E-01	1.0927E-01	3.3623E-02	3.4216E-02
9	4.3432E 01	2.6742E 01	1.4320E 01	9.2862E 00	5.3400E 00	1.9043E 00	4.4074E-01	1.4212E-01	7.2237E-02	4.4400E-02
10	1.1317E 01	6.0734E 00	3.6363E 00	2.3140E 00	1.3701E 00	4.6404E-01	1.0374E-01	3.3693E-02	1.7000E-02	1.0306E-02
11	7.2620E 00	4.3330E 00	2.2906E 00	1.4436E 00	8.3209E-01	2.8080E-01	6.4083E-02	2.0331E-02	1.0330E-02	6.2934E-03
12	6.9730E 00	4.1379E 00	2.1633E 00	1.3370E 00	7.9799E-01	2.6690E-01	3.9929E-02	1.0087E-02	9.4666E-03	3.7369E-03
13	9.3114E 00	3.3636E 00	2.9417E 00	1.8616E 00	1.1023E 00	3.7217E-01	8.4231E-02	2.6668E-02	1.3491E-02	8.1630E-03
14	3.0379E 00	3.0932E 00	1.6316E 00	1.0431E 00	6.1037E-01	2.0926E-01	4.7610E-02	1.3174E-02	7.6324E-03	4.6733E-03
15	6.7633E 00	4.1930E 00	2.2406E 00	1.4143E 00	8.3303E-01	2.8364E-01	6.4036E-02	2.0789E-02	1.0133E-02	6.4327E-03
16	1.1931E 01	7.4704E 00	4.0296E 00	2.3327E 00	1.3133E 00	3.1340E-01	1.1902E-01	3.8442E-02	1.9379E-02	1.2046E-02

Source: Systems Applications, Incorporated.

points. There are 96 (6 x 16) polar grid points within this range. Associated with each of these grid points, at which the concentration is known, is a smaller polar sector bounded by two concentric arcs and two radial lines. The boundary concentric arcs were defined by radii of 0.1, 0.25, 0.4, 0.6, 0.8, 1.2, and 2.8 km in this study, and the boundary radial lines were drawn right in the middle of two wind directions. Each of these concentration grid points was assigned to the nearest ED/BG centroid identified from the MED-X data set. The population at each centroid was then apportioned among all concentration grid points assigned to that centroid. The exact land area within each polar cell was considered in the apportionment, and the population density was assumed to be the same for all grid cells assigned to a single centroid. Both concentration and population counts were thus available for each polar grid point.

Log-log linear interpolation was used to estimate the concentration at each ED/BG population centroid located between 2.8 km and 20 km from the source. Concentration estimates for 80 (5 x 16) grid points (receptors at 2.0, 5.0, 10.0, 15.0, and 20.0 km from the source along each of the sixteen directions) resulting from dispersion modeling were used here as reference points for this interpolation. For each ED/BG centroid, four reference points were located as the four corners of the polar sector in which the centroid is located. These four reference points would surround the centroid as depicted in Figure 10. As shown in Figures 6, 7, and 8, there is a linear relationship between the logarithm of concentrations and the logarithm of distances for receptors more than 2 km away from the source. This relationship was used to estimate the concentrations at points E and F (see Figure 10). These estimates, together with the polar angles, were then used to interpolate the concentration at the centroid. Using the two-level approach, concentrations and populations wre paired up for the 96 concentration grid points within 2.8 km of the source and for all ED/BG centroids located between 2.8 km and 20 km from the source. The total dosage was then computed as follows:

$$\text{Total Annual Dosage } (\mu g/m^3\text{-person}) = \sum_{i=1}^{N} P_i C_i \quad ,$$

where P_i = the population at point i, C_i = the annual average concentration at point i, and N = the total number of grid points and ED/BG centroids with a specified combination of concentration and population (representing the entire area within 20 km of the source).

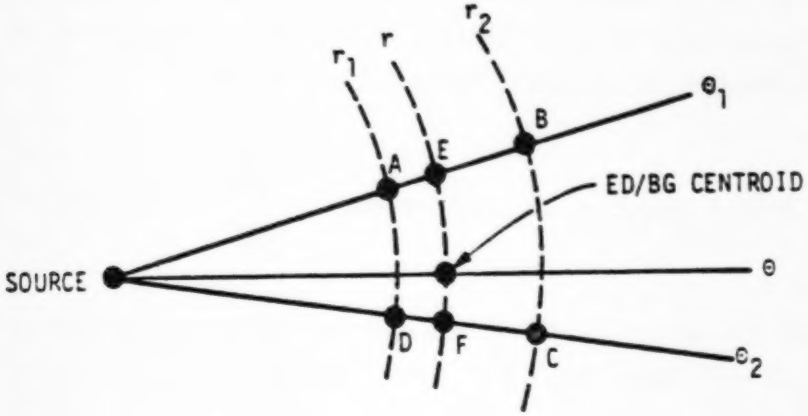


FIGURE 10. REFERENCE POINTS FOR AN ED/BG CENTROID

The population exposed to each of a number of concentration levels, L_j, was computed by:

$$\text{Exposure to } L_j \text{ (person)} = \sum_{i=1}^{N} P_i S_i(C_i, L_j) \quad ,$$

where

$$S_i = \begin{cases} 0 \quad , & \text{if } C_i < L_j \\ 1 \quad , & \text{if } C_i \geq L_j \end{cases} \quad .$$

The dosage of the fraction of the population that is exposed to concentrations greater than or equal to each of a number of concentration levels, L_j, was computed by using the following summation:

$$\text{Annual Dosage at } L_j \ (\mu g/m^3\text{-person}) = \sum_{i=1}^{N} P_i C_i S_i (C_i, L_j) \quad .$$

Note that the annual dosage at the minimum concentration within 20 km of the source will equal the total annual dosage.

The concentration levels at which exposure is to be estimated can be selected either manually or by an exponential function coded in the program. A suggested approach is to select the desired number of concentration levels, examine the exposure computed at the program-determined exposure levels, and then compute the exposures at selected levels.

The version of the MED-X data file used in these estimations includes the 1970 census data, so both exposure and dosage have to be adjusted to the 1978 levels. The 1978 to 1970 population ratio at the county level was used as the adjustment factor in this study. The exposure algorithm program was used to estimate the exposure/dosage for each of the major point sources and total nationwide exposure/dosage.

PROTOTYPE POINT SOURCE EXPOSURE AND DOSAGE ESTIMATION APPROACH

Significant amounts of chemicals are emitted from point sources that, practically, can only be treated generically. Such sources may include power plants, refineries, solvent degreasers, solvent users, gas stations, etc.; they are too numerous to be treated individually as point sources, and yet the spatial distributions of their emissions are not sufficiently uniform to be treated as area source emissions.

SAI conducted a study to compare two approaches for estimating the exposure-dosage resulting from chemical emissions from point sources treated as classes. The first approach assumes that these sources are area sources and that the Hanna-Gifford Model can be used to estimate atmospheric concentrations. This approach was applied to estimate the benzene concentration/dosage resulting from gasoline station emissions in an EPA report on human exposure to atmospheric benzene (Mara and Lee, 1978). In the alternative approach, model or prototype sources were defined; exposure estimates for each model source were developed in the same fashion as they were for major, specifically identified point sources. The results were then multiplied by the estimated number of sources of the same type to obtain national totals.

Trichloroethylene emitted from metal degreasing facilities is used as an example in this comparison study. Trichloroethylene has been the historical favorite for vapor degreasing uses, but regulations have been instituted regarding its use for metal cleaning because of its toxicity, its photochemical reactivity, and the resultant formation of undesirable byproducts. Vapor degreasers (VD) lose a relatively smaller portion of their solvents in waste material and as liquid carryout than do cold degreasers (CD). For both VDs and CDs, most (> 99 percent) of the emissions are those vapors that diffuse from the degreasers. Trichloroethylene vapor degreasing emissions are estimated by HI to have been 104,550 metric tons in 1978, or 99 percent of the total amount of trichloroethylene consumed for this purpose (see Attachment A). An estimated 15 percent of trichloroethylene consumed in metal degreasing operations was used in cold cleaning equipment. The remaining 85 percent was used in open top vapor degreasers (OTVDs) and conveyorized vapor degreasers (CVDs). The averaging emissions rates per unit and the total number of units in operation nationwide are shown in Table 15.

TABLE 15. NATIONWIDE TRICHLOROETHYLENE EMISSIONS FROM SOLVENT DEGREASERS

Type of Degreaser	National Emissions (metric tons/yr)	Number of Degreasers	Average Emissions Rate per Degreaser (g/sec)
Cold degreaser	14,950	49,770	0.0095
Open top vapor degreaser	55,570	6,110	0.288
Conveyorized vapor degreaser	33,340	1,232	0.858
Total	104,550	59,382	--

Source: Hydroscience, Incorporated, Knoxville, Tennessee, trichloroethylene emissions summary; included in attached species report.

In this study, model sources were defined for each of the nine geographic regions in the United States. Figure 11 displays the nine regions. The average emissions rate per degreaser, as listed in Table 15, is assumed applicable to all nine regions, and the deviations from the average rates are regarded as insignificant in terms of their influence on the overall exposure-dosage estimates. Therefore, there are three types of model sources in each region for trichloroethylene, and their emissions rates were assumed to be the average rates as listed in Table 15. However, for some model sources of other chemicals, the emissions rates may be different from region to region.

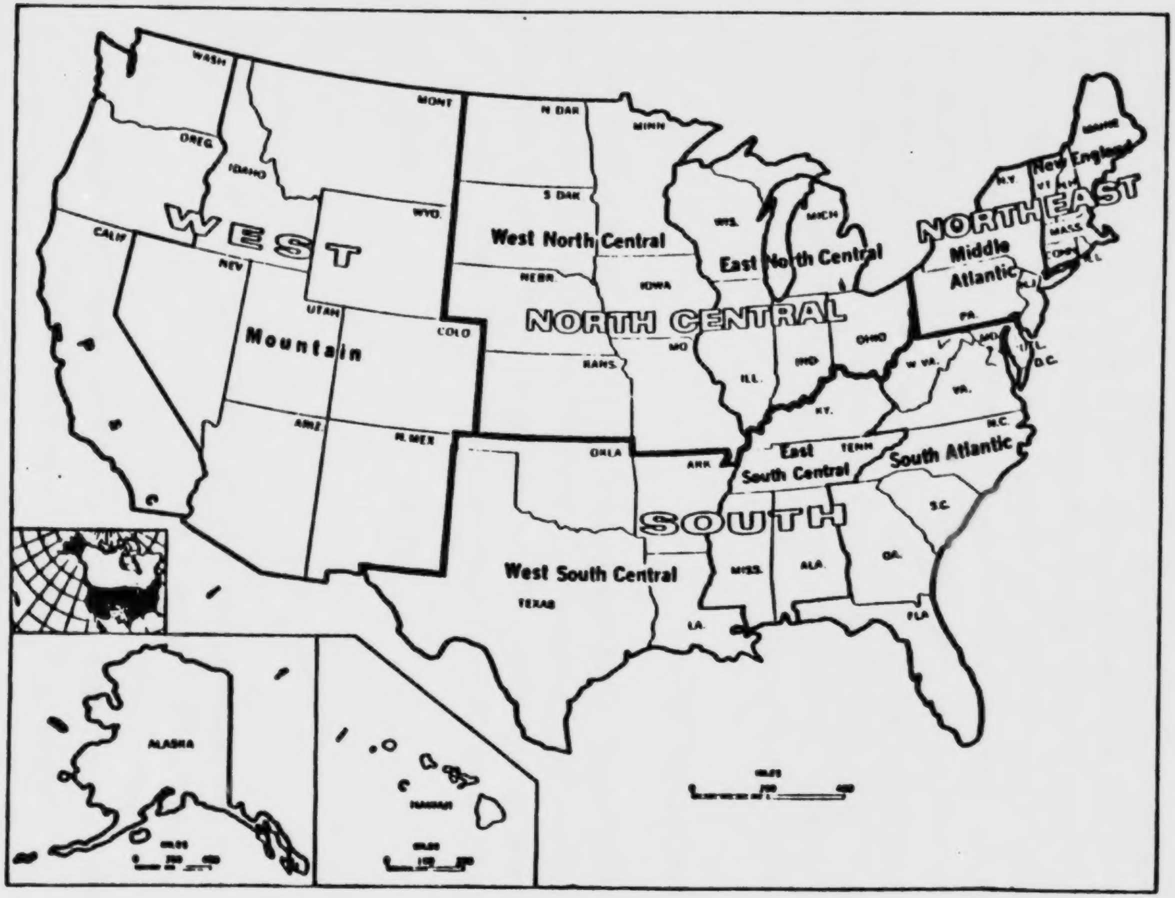

WEST
Mountain
NORTH CENTRAL
West North Central
East North Central
NORTHEAST
New England
Middle Atlantic
SOUTH
South Atlantic
East South Central
West South Central
WASH
OREG
IDAHO
MONT
WYO
CALIF
NEV
UTAH
COLO
ARIZ
N MEX
N DAK
S DAK
NEBR
KANS
MINN
IOWA
MO
WIS
MICH
ILL
IND
OHIO
OKLA
TEXAS
ARK
LA
MISS
ALA
KY
TENN
GA
FLA
S.C.
N.C.
VA
W VA
PA
N.Y.
VT
N.H.
MAINE
MASS
CONN
R.I.
N.J.
DEL
MD
D.C.
ALASKA
HAWAII

FIGURE 11. U.S. GEOGRAPHIC REGIONS

Degreasers that use trichloroethylene as a solvent are usually employed in the manufacturing industry; the population exposed to emissions from this type of source resides mostly in urbanized areas. In this study, all trichloroethylene-using degreasers were assumed to be located in urbanized areas with populations of more than 25,000. These urbanized areas were also the major exposed areas. An attempt was made to estimate the total land area in each region, and the average population density in these urbanized areas for each region was also derived. Table 16 lists these statistics together with the number of each of the three types of degreasers in each of the nine regions. The 1978 population density in these urbanized areas was assumed not to differ significantly from the 1972 figure. The population and land area data were from the 1970 census data (U.S. Bureau of the Census, 1973) and data on the number of degreasers were estimates made by HI.

Uniform Emissions Approach

In this approach, trichloroethylene was assumed to be emitted uniformly throughout the area covered. To calculate the average annual area-wide trichloroethylene concentrations, χ, resulting from vapor degreasing emissions, the Hanna-Gifford dispersion equation was used:

$$\chi = \frac{225\ Q}{u} \quad , \qquad (16)$$

where

Q = average emissions rate of trichloroethylene from unit area ($\mu g/sec - m^2$),

u = average wind speed (m/sec),

225 = an empirical factor derived from several previous studies on relatively large scale urban areas ($\sim 400\ km^2$) and under neutral atmospheric stability.

TABLE 18. 1970 POPULATION DENSITY AND NUMBER OF TRICHLOROETHYLENE-USING DEGREASERS IN THE NINE GEOGRAPHIC REGIONS

		Statistics in Urbanized Areas*			Number of Degreasers†		
Region Code	Region	Population (in thousands)	Area (km^2)	Density (persons/km^2)	CD§	OTVD**	CVD††
1	New England	8,098	7,650	1,059	2,991	560	113
2	Middle Atlantic	27,959	14,084	1,985	7,760	1,158	244
3	East North Central	26,506	19,543	1,356	13,179	1,742	405
4	West North Central	8,450	8,402	1,006	4,362	452	80
5	South Atlantic	15,862	14,102	1,125	6,005	465	84
6	East South Central	4,173	4,986	837	2,944	265	52
7	West South Central	10,948	12,312	889	4,832	398	68
8	Mountain	4,692	4,772	983	1,806	174	21
9	Pacific	20,582	14,335	1,436	5,893	896	165

---

* Source: U.S. Bureau of Census, 1973.

† Source: Hydroscience, Incorporated, Knoxville, Tennessee, trichloroethylene emissions summary included in Attachment A.

§ Cold Degreaser.

** Open Top Vapor Degreaser.

†† Conveyorized Vapor Degreaser.

Since this approach does not consider concentration patterns, patterns of wind variability were not judged to be pertinent, and a mean, national average wind was used. The average U.S. wind speed was determined to be 5.5 m/sec by weighting regional average wind speeds by population, (Mara and Lee, 1978). Because it was assumed that all of the vapor degreasers are located in Urbanized Areas, the total land area of the Urbanized Areas in the United States (U.S. Bureau of the Census, 1973) was used in the estimation of unit area emissions rates (Q). Table 17 lists the major parameters used in this approach, together with the estimated concentration-dosage results. It should be noted that no information on the differentiation of levels of exposure to the populations residing in the Urbanized Areas is available, and only the average exposed concentration is derived from this approach.

TABLE 17. MAJOR PARAMETERS AND CONCENTRATION-DOSAGE RESULTS OF THE UNIFORM EMISSIONS APPROACH

Major Parameters	Concentration-Dosage Results	Information Source
Total trichloroethylene vapor degreasing emissions	104,550 metric tons/yr	Hydroscience, Incorporated
Total Urbanized Area	100,190 km^2	U.S Census Bureau (1973)
Unit area emissions rate, Q	0.0331 $\mu g/sec - m^2$	SAI computations
Average U. S. wind speed, u	5.5 m/sec	Mara and Lee (1978)
Average exposed concentration, χ	1.354 $\mu g/m^3$	SAI computations
Total population in Urbanized Areas in 1978	135 million*	U.S Census Bureau (1973)
Total U. S. annual dosage	1.88×10^8 ($\mu g/m^3$) - person	SAI computations

---

* Based on 1970 population in Urbanized Areas, 127,270,000, and the projected 1978 to 1970 population ratio of 218 million/205 million.

Prototype Point Source Approach

In this approach, concentration-dosage patterns were estimated for emissions from three model sources--a CD, an OTVD, and a CVD--for the nine regions. The emissions rates of these three model sources were assumed to be constants, as shown in Table 17.

A set of STAR (STability ARray) stations with climatological conditions that are typical of those in the nine regions were selected as the base for conducting regional model source dispersion modeling (see Table 10).

Trichloroethylene is quite reactive toward ambient hydroxyl radical (OH)--about one-fifth as reactive as propylene. Its reaction with ozone molecules is, however, very slow. Therefore, the psuedo-first-order reaction rate constant of trichloroethylene in the ambient air in the daytime would be about 1.68×10^{-3} min^{-1}; during the night it would be close to zero since atmospheric reactions toward OH species occur only in the daytime.

Most of the trichloroethylene-using degreasing units--cold degreasers or vapor degreasers--are housed inside a building or other shelter. Emissions are from the venting system of the shelter. The emissions parameters for these three types of degreasers are summarized in Table 18.

TABLE 18. EMISSIONS PARAMETERS FOR PROTOTYPE POINT SOURCES OF TRICHLOROETHYLENE

Source Type	Vent Height (m)	Building Cross-Section (m^2)	Vent Diameter (m)	Vent Velocity (m/sec)	Vent Temperature (°K)
Cold cleaners	4.5	50	0.15	0.2	--
Open top vapor degreasers	4.5	50	0.15	0.2	327
Conveyorized vapor degreasers	4.5	50	0.15	0.2	327

Source: Hydroscience, Incorporated, Knoxville, Tennessee; trichloroethylene report, attached.

The major steps involved in deriving the exposure-dosage estimates can be delineated as follows:

> Based on emissions characteristics, photochemical reactivity, and the STAR data of the selected stations, the concentration patterns resulting from emissions from the three model sources were determined individually for all nine regions by using the same dispersion modeling technique developed for major point sources. As an example, the modeling results of concentration patterns around a model OTVD in the New England Region are shown in Table 19.

> Table 20 lists the distances between the concentration centers (receptors) and the source, the distances of boundary areas of the sectors away from the source, and the land area of sectors corresponding to each concentration center. The average population density in the urbanized areas for the nine regions, together with the specific sector land area assigned to each concentration center, were used to estimate the population exposed to different concentrations. To make this estimate, the average population density is multiplied by the sector land area corres-

TABLE 19. TRICHLOROETHYLENE CONCENTRATION PATTERN AROUND A MODEL OPEN TOP VAPOR DEGREASER IN NEW ENGLAND REGION

(Concentration per unit emission rate in seconds/meter^3)

Wind Direction*	DOWNWIND DISTANCE (KM) 0.2	0.3	0.5	0.7	1.0	2.0	5.0	10.0	15.0	20.0
1	1.28659E-05	6.42836E-06	2.69983E-06	1.52067E-06	8.30281E-07	2.60146E-07	5.68220E-08	1.73995E-08	8.09398E-09	4.87314E-09
2	5.00083E-06	2.55914E-06	1.07598E-06	6.05556E-07	3.30591E-07	1.03473E-07	2.24988E-08	6.83530E-09	3.27358E-09	1.88002E-09
3	5.16483E-06	2.44013E-06	1.10764E-06	6.23386E-07	3.40856E-07	1.06330E-07	2.31468E-08	7.06647E-09	3.40463E-09	1.97656E-09
4	4.80395E-06	2.45290E-06	1.02730E-06	5.77649E-07	3.14820E-07	9.83305E-08	2.14295E-08	6.56031E-09	3.17621E-09	1.84930E-09
5	1.02669E-05	5.22134E-06	2.17767E-06	1.22104E-06	6.63870E-07	2.06225E-07	4.47729E-08	1.37332E-08	6.65639E-09	3.88607E-09
6	8.87362E-06	4.58587E-06	1.87584E-06	1.04988E-06	5.69529E-07	1.76321E-07	3.80236E-08	1.15711E-08	5.57882E-09	3.23229E-09
7	6.35746E-06	3.15972E-06	1.30621E-06	7.27982E-07	3.92884E-07	1.20289E-07	2.54283E-08	7.57217E-09	3.57777E-09	2.03932E-09
8	4.43689E-06	2.26194E-06	9.48822E-07	5.31070E-07	3.08912E-07	8.97787E-08	1.92981E-08	5.78729E-09	2.73817E-09	1.55972E-09
9	1.26799E-05	6.48388E-06	2.72178E-06	1.53258E-06	8.36468E-07	2.61871E-07	5.71898E-08	1.74582E-08	8.40064E-09	4.86612E-09
10	8.61812E-06	4.41538E-06	1.85832E-06	1.04842E-06	5.73625E-07	1.80721E-07	3.99846E-08	1.24737E-08	6.12237E-09	3.61288E-09
11	8.52627E-06	4.35895E-06	1.83889E-06	1.03094E-06	5.63224E-07	1.77036E-07	3.91775E-08	1.22719E-08	6.05189E-09	3.58773E-09
12	1.22535E-05	6.25142E-06	2.61889E-06	1.47242E-06	8.03824E-07	2.51654E-07	5.55223E-08	1.73772E-08	8.57826E-09	5.08282E-09
13	1.25593E-05	6.39956E-06	2.67661E-06	1.50419E-06	8.19792E-07	2.56737E-07	5.67599E-08	1.78759E-08	8.87922E-09	5.30465E-09
14	1.27037E-05	6.50552E-06	2.73718E-06	1.54427E-06	8.45283E-07	2.66835E-07	5.93638E-08	1.88738E-08	9.40484E-09	5.62918E-09
15	1.23575E-05	6.32044E-06	2.65486E-06	1.49682E-06	8.17614E-07	2.57274E-07	5.70496E-08	1.79211E-08	8.83968E-09	5.26399E-09
16	8.47944E-06	4.33637E-06	1.82088E-06	1.02369E-06	5.60231E-07	1.75899E-07	3.87349E-08	1.20288E-08	5.88898E-09	3.48789E-09

---

[*] 1 = N, 2 = NNE, 3 = NE, etc.

Source: Systems Applications, Incorporated computations.

TABLE 20. LAND AREAS FOR SPECIFIED CONCENTRATION CENTERS

Distance of Concentration Center from Source (km)	Distance of Boundary Arc from Source, r (km)	πr^2 (km^2)	Land Area of Sector, $\Delta\pi r^2/16$ (km^2)
	0.1*	0.0314	
0.2			0.0103
	0.25	0.196	
0.3			0.0192
	0.4	0.503	
0.5			0.0393
	0.6	1.131	
0.7			0.071
	0.85	2.270	
1.0			0.300
	1.5	7.069	
2.0			1.963
	3.5	38.48	
5.0			8.64
	7.5	176.7	
10.0			19.64
	12.5	490.9	
15.0			29.44
	17.5	962.0	
20.0			39.25
	22.5	1590.0	

---

* The radius of prototype plant property is assumed to be 100 meters.

ponding to the specific concentration center. The dosage corresponding to the specific concentration center can then be estimated by multiplying the exposed population by the concentration to which it is exposed. Therefore, for each model source in each of the nine regions, there were three corresponding matrices--one for the concentration pattern, one for the exposed population, and one for the dosage estimates.

The exposure-dosage data for each model source were then summarized according to their corresponding exposed concentration. The population exposed to concentrations greater than or equal to each of a number of concentration levels, L_j, in the vicinity of a model source m in region r was computed by:

$$e_{m,r} = \sum_{i=1}^{N} P_i S_i \ (C_i, L_j) \quad , \qquad (17)$$

where

N = the total number of concentration points (with 10 receptors along each of 16 wind directions: 10 x 16 = 160),

P_i = the population corresponding to concentration center i,

C_i = the annual average exposed concentration at concentration center i,

$$S_i = \begin{cases} 0, \text{ if } C_i < L_j \\ 1, \text{ if } C_i \geq L_j \end{cases} \quad .$$

The population exposed to trichloroethylene concentrations larger than or equal to different concentration levels resulting from the three model sources in the nine regions is listed in Table 21. The dosage of the fraction of population that is exposed to concentrations greater than or equal to each of a number of concentration levels, L_j, in the vicinity of a model source m in region r was computed by:

$$d_{m,r} = \sum_{i=1}^{N} P_i C_i S_i \ (C_i, L_j) \quad . \qquad (18)$$

The dosages of trichloroethylene as a function of exposed concentration levels for the three types of model degreasers in the nine regions are shown in Table 22. The exposure-dosage patterns for each of the three model sources located in each of the nine regions can be used as the bases for estimating the total exposure-dosage as a function of exposed concentration levels in each individual region by:

$$(\text{Total exposure at } L_j)_r = \sum_{m=1}^{3} (e_{m,r} \times n_{m,r}) \quad , \qquad (19)$$

$$(\text{Total dosage at } L_j)_r = \sum_{m=1}^{3} (d_{m,r} \times n_{m,r}) \quad , \qquad (20)$$

TABLE 21. POPULATION EXPOSURE TO TRICHLOROETHYLENE EMITTED FROM A TYPICAL DEGREASER

(a) Cold Degreaser

Concentration Level (μg/m³)	Number of Persons Exposed by Geographic Region								
	1	2	3	4	5	6	7	8	9
0.25	0	0	9	7	0	26	0	66	58
0.10	105	109	67	63	400	254	30	354	283
0.05	408	369	152	212	1,022	720	86	1,213	862
0.025	1,046	907	363	497	2,015	1,620	197	3,688	2,461

TABLE 21 (Continued)

(b) Open Top Vapor Degreaser

Concentration Level (μg/m³)	Number of Persons Exposed by Geographic Region								
	1	2	3	4	5	6	7	8	9
5.0	0	8	17	75	130	115	8	253	166
2.5	62	98	54	223	806	426	43	1,063	442
1.0	282	346	165	779	2,409	1,271	177	3,247	1,429
0.5	680	834	495	1,796	5,484	3,328	405	9,253	4,083
0.25	1,416	2,038	1,045	4,491	17,334	10,075	1,123	17,816	7,232
0.10	4,392	6,692	3,806	17,433	51,612	26,415	3,794	65,517	31,250
0.05	21,607	21,243	7,061	28,318	127,741	61,509	8,063	188,505	49,442
0.025	28,928	35,924	16,418	67,033	219,354	79,622	15,251	282,184	119,420

TABLE 21 (Concluded)

(c) Conveyorized Vapor Degreaser

Concentration Level ($\mu g/m^3$)	Number of Persons Exposed by Geographic Region								
	1	2	3	4	5	6	7	8	9
5.0	152	137	84	422	1,928	573	58	2,770	885
2.5	252	324	182	998	3,964	1,658	141	6,240	1,960
1.0	920	1,193	647	3,812	15,000	4,577	560	18,100	6,900
0.5	2,673	3,275	1,390	9,075	30,710	13,250	1,100	55,700	18,850
0.25	4,292	7,090	3,234	23,500	88,100	34,400	3,220	100,000	29,700
0.10	19,470	20,901	9,358	55,750	186,900	69,200	8,400	415,200	118,200
0.05	30,000	38,074	16,889	128,750	478,600	160,800	20,000	561,900	173,300

Source: Systems Applications, Incorporated computations.

TABLE 22. TRICHLOROETHYLENE DOSAGE RESULTING FROM MODEL DEGREASER EMISSIONS

[(µg/m^3)/person]

(a) Cold Degreaser

Concentration Level (µg/m^3)	Geographic Region								
	1	2	3	4	5	6	7	8	9
0.25	0	0	3	2	0	10	0	22	20
0.10	13	14	11	12	56	44	4	66	55
0.05	33	33	17	23	97	77	8	130	97
0.025	54	52	24	34	130	107	12	210	149
0.010	78	84	37	59	213	164	19	288	210
0*	471	447	135	238	903	574	96	1,185	804

TABLE 24 (Continued)

(b) Open Top Vapor Degreaser

Concentration Level ($\mu g/m^3$)	Geographic Region 1	2	3	4	5	6	7	8	9
5.0	0	51	118	486	839	875	47	1,948	1,227
2.5	211	334	252	951	3,247	1,955	166	4,529	2,076
1.0	580	719	425	1,759	5,828	3,215	372	7,931	3,638
0.5	854	1,045	643	2,478	8,045	4,642	525	11,954	5,438
0.25	1,121	1,459	827	3,385	12,237	6,755	769	14,770	6,518
0.10	1,707	2,184	1,251	5,243	17,269	8,906	1,143	22,586	10,502
0*	6,268	7,012	2,797	13,009	46,667	20,000	3,392	56,667	23,884

TABLE 24 (Concluded)

(c) Conveyorized Vapor Degreaser

Concentration Level ($\mu g/m^3$)	Geographic Region 1	2	3	4	5	6	7	8	9
5.0	1,115	1,180	860	4,260	17,700	6,440	525	27,380	9,450
2.5	1,500	1,910	1,180	6,260	24,600	10,020	825	39,570	13,200
1.0	2,575	3,230	1,890	10,400	40,700	14,230	1,425	59,050	21,090
0.50	3,820	4,630	2,380	14,000	52,300	20,380	1,825	85,700	29,300
0.25	4,460	5,940	3,140	18,750	72,100	26,730	2,560	103,300	35,800
0.10	7,280	8,360	4,100	23,500	91,200	31,900	3,430	150,500	48,300
0*	15,800	17,870	7,010	44,100	178,600	53,600	7,132	257,000	81,200

---

* Total dosage resulting from emissions from one model source in a surrounding area (22.5 km radius).

where $n_{m,r}$ is the total number of model source m (a CD, an OTVD, or a CVD) in region r. On the other hand, the total nation-wide exposure-dosage resulting from emissions from one type of model source can be derived by

$$(\text{Total exposure at } L_j)_m = \sum_{m=1}^{9} (e_{m,r} \times n_{m,r}) \quad , \qquad (21)$$

$$(\text{Total dosage at } L_j)_m = \sum_{r=1}^{9} (d_{m,r} \times n_{m,r}) \quad . \qquad (22)$$

The following two equations were used to estimate the total U.S. exposure-dosage for the fraction of the population exposed to concentrations of trichloroethylene greater than or equal to a number of concentration levels, L_j, emitted from this source category:

$$\text{Total exposure at } L_j = \sum_{r=1}^{9} \sum_{m=1}^{3} (e_{m,r} \times n_{m,r}) \quad , \qquad (23)$$

$$\text{Total dosage at } L_j = \sum_{r=1}^{9} \sum_{m=1}^{3} (d_{m,r} \times n_{m,r}) \quad . \qquad (24)$$

The results of such summations are shown in Tables 23, 24, and 25.

The two different approaches for computing total dosages resulting from emissions from trichloroethylene-using degreasers produce different results. By using the uniform emissions approach, the total U.S. dosage of trichloroethylene resulting from degreasing operations is computed to be 1.88×10^8 $\mu g/m^3$ - person (see Table 17), whereas use of the point source approach results in a dosage of 1.54×10^8 $\mu g/m^3$ - person (see Table 25). The two approaches can be compared by examining the nature and detail of the results they offer:

> Degreasing facilities are obviously not uniformly distributed in any siting area. They are point sources and produce typical point source concentration patterns. Thus, the exposure levels for receptors close to the source would be higher than those farther away. The point source approach would provide better differentiation of the exposed population and dosage at different concentration levels, whereas the uniform emissions approach would provide only a nationwide average exposure level. Tables 21, 22, and 25 list the exposure-dosage by different types of degreasers. These types of data are useful for risk analysis and regulatory decision making. For example, one may conclude from data listed in Table 25 that, although open top vapor degreasers contribute most to the total dosages, the conveyorized vapor degreasers contribute most to the dosage-exposure at high concentration levels.

> The dosage is defined here as the product of concentration and exposed population. Therefore, it is necessary to set an arbitrary boundary for dispersion-dosage estimates for emissions from point sources. In the point-sources

TABLE 23. NATIONWIDE TRICHLOROETHYLENE EXPOSURE RESULTING FROM EMISSIONS FROM DEGREASING OPERATIONS

Concentration Level ($\mu g/m^3$)	Thousands of Persons Exposed by Geographic Region									U.S. Total
	1	2	3	4	5	6	7	8	9	
25	0	0	2.2	1.2	0	1.4	0	1.7	7.2	13.6
10	4.4	6.9	13.4	16.2	51	14.1	1.0	25.3	87	219
5	17	43	63	68	222	60	7.1	102	295	879
2.5	63	192	167	180	708	199	27	317	719	2,570
1	262	693	550	656	238	575	108	945	2,420	8,590

Source: Systems Applications, Incorporated computations.

TABLE 24. NATIONWIDE TRICHLOROETHYLENE DOSAGE RESULTING FROM EMISSIONS FROM DEGREASING OPERATIONS

[10^6 ($\mu g/m^3$)/person]

Concentration Level ($\mu g/m^3$)	Geographic Region 1	2	3	4	5	6	7	8	9	U.S. Total
25	0	0	0.06	0.04	0	0.05	0	0.06	0.25	0.45
10	0.05	0.09	0.21	0.24	0.71	0.24	0.14	0.40	1.33	3.28
5	0.13	0.35	0.56	0.56	1.88	0.57	0.55	0.91	2.65	7.66
2.5	0.29	0.85	0.92	0.93	3.58	1.04	0.12	1.62	4.05	13.4
1	0.62	1.62	1.51	1.63	6.13	1.59	0.25	2.62	6.73	22.7
0.5	0.91	2.34	2.08	2.23	8.12	2.29	0.33	3.88	9.70	31.9
0.25	1.13	3.14	2.75	3.05	11.8	3.20	0.48	4.78	11.9	42.1
0.1	1.82	4.69	3.98	4.30	16.0	4.15	0.71	7.24	17.7	60.6
0.05	2.59	6.24	4.68	5.12	20.6	5.18	0.90	8.81	19.7	73.9
0*	6.70	15.9	9.50	10.5	42.1	9.78	2.30	17.4	39.6	154

---

* Total dosage, assuming the exposed area is within 22.5 km radius of the source.

Source: Systems Applications, Incorporated computations.

TABLE 25. NATIONWIDE TRICHLOROETHYLENE EXPOSURES AND DOSAGES RESULTING FROM EMISSIONS FROM DIFFERENT TYPES OF DEGREASING FACILITIES

Concentration Level ($\mu g/m^3$)	Exposure (10^6 persons exposed)				Dosage [10^6 ($\mu g/m^3$)/person]			
	CD*	OTVD†	CVD§	Total	CD	OTVD	CVD	Total
5	0	0.36	0.52	0.88	0	2.56	5.10	7.66
2.5	0	1.43	1.14	2.57	0	6.12	7.28	13.4
1	0	4.57	4.02	8.59	0	11.0	11.7	22.7
0.5	0	11.9	10.0	21.9	0	16.1	15.8	31.9
0.25	--	--	--	--	0.24	21.5	20.4	42.1
0.1	--	--	--	--	1.28	32.2	27.1	60.6
0.05	--	--	--	--	2.34	40.5	31.0	73.9
0.025	--	--	--	--	3.45	47.3	36.5	87.2
0.01	--	--	--	--	5.25	58.3	42.5	106
0**	--	--	--	--	7.39	82.0	49.6	154

---

* Cold degreaser.

† Open top degreaser.

§ Conveyorized vapor degreaser.

** Total dosage, assuming the exposed area is within 22.5 km radius of the source.

Source: Systems Applications, Incorporated computations.

> approach, the impact area of one model source is defined as being within a 22.5 km radius of the source. As revealed by the data in Tables 26 and 27 , dosages decrease rapidly with decreasing concentration levels; thus, dosages also decrease dramatically as one moves farther away from the source. This convergency nature of the dosages as a function of concentrations indicates that the dosages contributed by exposures outside the arbitrarily defined impact areas (r < 22.5 km) would not be significant compared to the total dosage within the impact area.

The total dosage for a specified population can be estimated by using either of the following two methods:

> Estimate the dosage resulting from emissions from each nearby source and sum them.
> Estimate the overall exposed concentration level and then compute the total dosage.

Since the overall exposed concentration level cannot be derived because of the lack of data on geographical distributions of sources, the first method was used here.

By examining the results derived from adoption of the two approaches and considering the above information, the study team concluded that the point source approach would be more appropriate for dealing with all general point sources in this study. However, not all the data involved would be listed in each individual chemical exposure-dosage summary, and only the modeling results and the major input data, such as the number of sources in each region and the emissions characteristics, would be delineated.

AREA SOURCE MODELING APPROACH

Certain of the chemicals to be studied in the Human Exposure program are emitted from area sources that cannot be specified in detail; such emissions must be inferred by relating them to population, motor vehicles, etc. However, different urbanized areas with different levels of population/motor vehicles concentrations are likely to be exposed to different levels of these ambient chemicals under different environmental settings. Because the number of urbanized areas to be studied is quite large, it is necessary to use a simple dispersion algorithm to estimate concentration patterns. The Hanna-Gifford urban area dispersion algorithm (Hanna, 1971; Hanna and Gifford, 1973) has proved to be a simple but physically realistic model capable of estimating atmospheric pollutant concentrations caused by area source emissions in cities. The basic Hanna-Gifford Equation is given as:

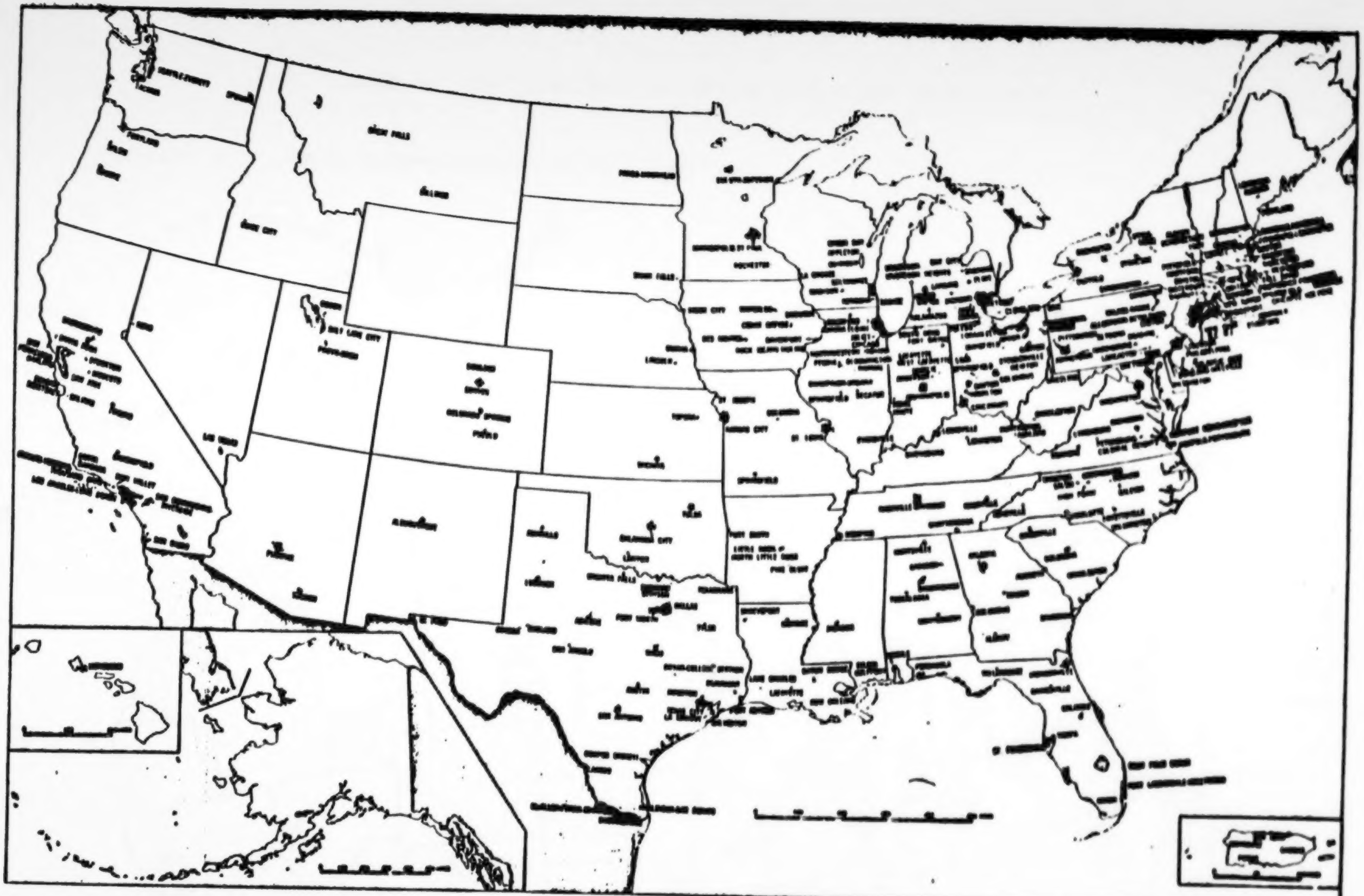
$$X = CQ_0/\mu \quad , \qquad (25)$$

where X is the air pollutant concentration, Q_0 is the effective emissions rate per unit area, and μ is the average wind speed. The parameter C, generally referred to as the Hanna-Gifford coefficient, is a weak function of the city size; it may be taken to be approximately constant. Theoretically, the parameter C is given by:

$$C = (2/\pi)^{1/2} \cdot x^{1-b} / [a(1-b)]^{-1} \quad , \qquad (25)$$

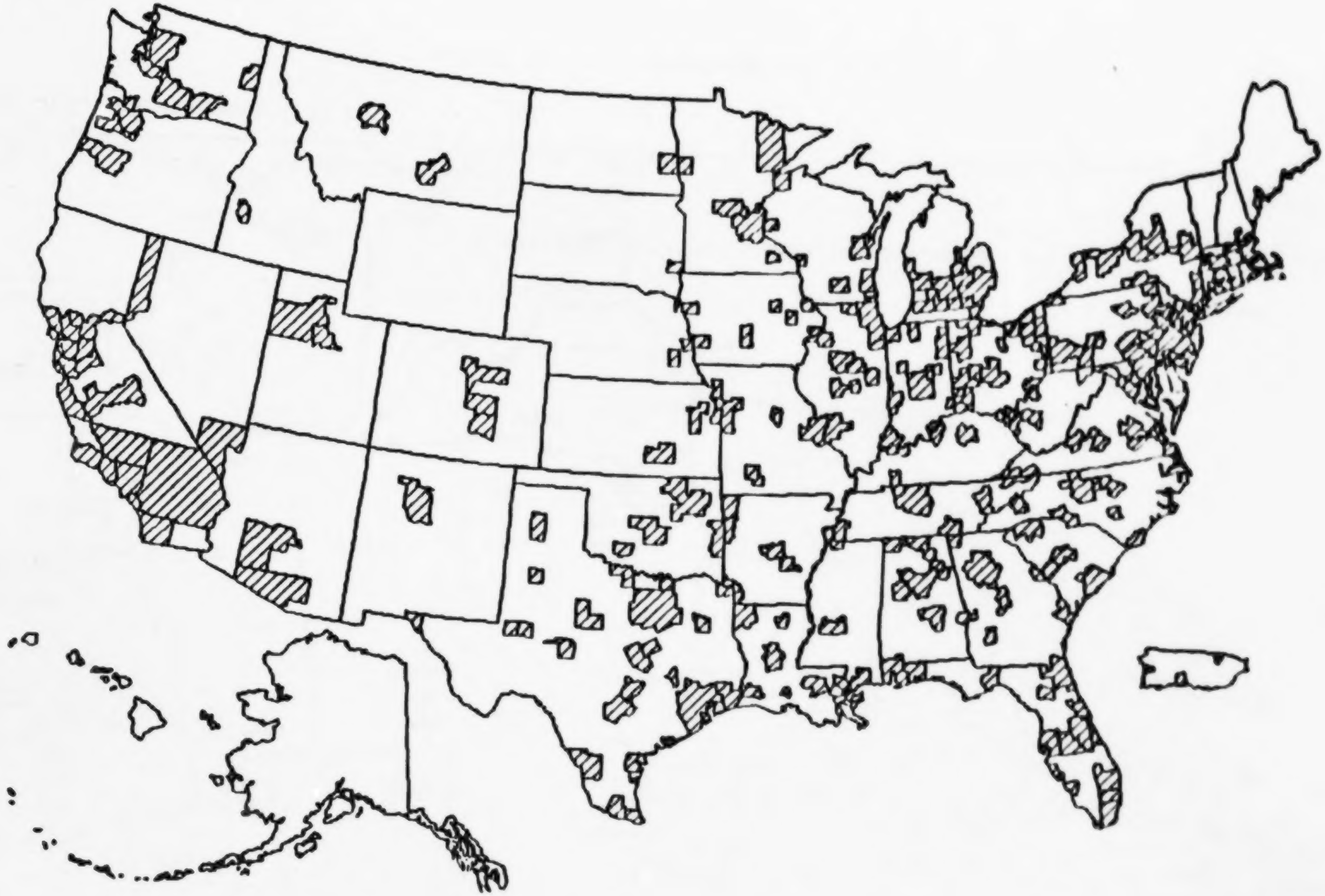
where χ is the distance from a receptor point to the upwind edge of the area source. The constants a and b are defined by the vertical atmospheric diffusion length, $\sigma_z = a\chi^b$. Values of a and b for different atmospheric dispersion conditions have been discussed by Pasquill (1970, 1971). The parameter C can be estimated for various combinations of the stability factors a and b and by assuming that χ equals half the city size (Hanna, 1978). For example, 213 would be an appropriate value of C for a city with a land area of 400 km^2 under Pasquill Class D stability (while a = 0.15 and b = 0.75). Specific values of the parameter C have been empirically estimated by Hanna and Gifford (1973) for a large number of U.S. cities based on a large quantity of air quality data, average annual emissions, and meteorological conditions. The mean value of C has been found to equal 225, with a standard deviation roughly half that magnitude. This value of the parameter C has been recommended for use in evaluating an area source by the EPA (1977a,b) if removal and decay processes may be neglected. Because a large number of cities with different sizes would be considered in this study, the theoretical estimates of the parameter C were calculated by using Equation 2 and by assuming Pasquill Class D stability as the average long-term meteorological condition. This is the EPA-recommended approach.

Three types of cities were assessed in this study. Type I cities include all 248 Urbanized Areas in the United States, as determined by the U.S. Bureau of Census (1973). An "Urbanized Area" consists of a central city or cities with 50,000 inhabitants or more in 1960 and the surrounding densely settled territory. Figure 12 displays the location and size of these Urbanized Areas. The widely used data bases for Standard Metropolitan Statistical Areas (SMSAs), displayed in Figure 13, were not used here. A comparison of Figures 12 and 13 shows clearly that the delineation of Urbanized Areas provides a better separation of urban and rural populations in the vicinity of large metropolitan areas. Most of the


BOISE CITY
SALT LAKE CITY
LAS VEGAS
PUEBLO
SIOUX FALLS
ROCHESTER
LINCOLN
KANSAS CITY
OKLAHOMA CITY
LAWTON
WICHITA FALLS
FORT SMITH
PINE BLUFF
FORT WORTH
DALLAS

Source: U.S. Census Bureau (1973).

FIGURE 12. U.S. URBANIZED AREAS (1970)



Source: U.S. Federal Highway Administration (1974).

FIGURE 18. U.S. STANDARD METROPOLITAN STATISTICAL AREAS (1970)

Urbanized Areas can be further divided into inner cities and urban fringe. The central cities were classified as inner cities and any Urbanized Areas outside the central cities were classified as urban fringe. The latest census data for the Urbanized Areas are based on the 1970 census survey results (U.S. Bureau of Census, 1973); accordingly, 1970 population data were used throughout this study even though more up-to-date population data (U.S. Bureau of Census, 1978) are currently available at other levels of population unit/grouping. The 1973 statistics on motor vehicle registrations in the SMSAs were obtained from the U.S. Federal Highway Administration (1974) and were used, together with population data, as the bases for estimating the number of automobiles and trucks and buses in the Urbanized Areas (for both inner city and urban fringe). These 1970 population and 1973 motor vehicle data were subsequently extrapolated to 1978 figures based on statistics at the state level. Table 32* lists the land areas, 1970 population, and 1973 motor vehicle data for Type I cities. The statistics for trucks include buses and all other heavy duty vehicles. The total 1970 population in these 248 Urbanized Areas is 118,446,000, which is about 59 percent of the total U.S. population.

Type II cities include all cities with a 1970 population larger than 25,000 but not located in any Urbanized Area. The total population residing in the 243 Type II cities is 8,594,000, which is about 4.3 percent of the total U.S. population. Table 33* lists the land area, the 1970 population, and 1973 motor vehicle data for these cities. These Type II city estimates used the same data sources and methodology as were used for Type I city estimations.

Type III cities have 1970 populations of more than 2,500 but are not included in Type I and Type II cities. There are over 1,000 cities and towns in the United States in this category. Therefore, a sample of 150 cities of this type was pulled from the list (U.S. Bureau of Census, 1973, Table B-2) using a random numbers table. Table 30* lists the land area, 1970 population, and 1973 motor vehicle data for these 150 cities and towns. The motor vehicle data estimates were based on statistics at the state level. The total population of these 150 cities and towns is 1,077,000 in 1970. It is about 5 percent of the total population (21,708,000) in all Type III cities. The exposure-dosage data estimated for the 150 cities/towns were scaled by the ratio of all Type III population to the sample population so as to represent exposure-dosage for all Type III cities. Type III cities represented about 11 percent of the total U.S. population in 1970.

---

* Because of their length, Tables 32 and 33 appear at the end of Section 3.

Most of the U.S. population (about 75 percent) is included in cities of Type I, II, or III. Chemical exposure-dosage in areas not represented is deemed insignificant because of the low concentrations and low population densities. As evidenced later in this report, this assumption--that less densely populated areas would be exposed to insignificant ambient concentrations--is valid. The atmospheric concentrations of chemicals resulting from area source emissions were shown to be much lower for residents in Type III cities than those in Type I cities. Rural population densities and, therefore, rural concentrations are even lower.

Chemical emissions from area sources of various categories are estimated and reported as national totals in the emissions summaries submitted by HI. These national total emissions estimates have to be distributed among cities of each of the three types. Depending on the nature of emitting sources, the distribution can be accomplished by one of the following methods:

---

* Because of its length, Table 30 appears at the end of Section 3.

- > Emissions from mobile sources can be distributed by the number of motor vehicles.
- > Emissions from home heating sources can be distributed by the product of population and per capita heating requirement.
- > Other stationary area sources can be distributed by population.

Table 26 lists, in addition to those data listed in Tables 32, 33, and 34, the necessary data for area source emissions distributions. These include the 1970 and 1978 state population data (U.S. Bureau of Census, 1979), 1973 and 1978 state motor vehicle data (U.S. Federal Highway Administration, 1978), statewide average wind speed, and state-wide average heating requirements in degree-days (U.S. Bureau of Census, 1979). The 1978 figures are estimates, as population/motor vehicle data for each of the three types of cities are not available for 1978. These data at the state level were used to project the growth. For example, Anniston, Alabama, is a Type II city with city code 1 (as shown in Table 29). Its 1970 population was 31,058, and there were 16,800/3,692 autos/trucks registered in 1973. To estimate the 1978 statistics, the state growth during the same period (as shown in Table 31) was used. The 1978 population in this city is estimated to be 31,508 x (3,724,000/3,444,000) = 34,070. The 1978 auto/truck figure can be estimated in the same way: 16,899 x (2,791,000/2,299,000) = 20,515; 3,692 x (2,791,000/2,299,000) = 4,482.

Three equations were used to distribute the area sources into each of the three types of cities (or urbanized areas). For mobile sources,

$$Q_M = \frac{EM}{A} \cdot \frac{a78 + t78 \cdot R}{117{,}147{,}000 + 31{,}921{,}000 \cdot R} \quad , \qquad (27)$$

TABLE 26. MAJOR STATE STATISTICS RELATED TO AREA SOURCE EMISSIONS DISTRIBUTION

State	Population* (in thousands) 1970	Population* (in thousands) 1978	No. of Vehicles† (in thousands) 1973	No. of Vehicles† (in thousands) 1978	Average Wind Speed§ (m/sec)	Average Heating§ (degree-day/year)
Alabama	3,444	3,724	2,299	2,791	4.4	1,684
Alaska	300	420	180	280	4.0	9,007
Arizona	1,771	2,365	1,379	1,630	3.0	1,552
Arkansas	1,923	2,176	1,195	1,501	3.9	3,354
California	19,953	22,153	13,238	15,514	4.1	2,568
Colorado	2,207	2,674	1,757	2,303	4.3	6,016
Connecticut	3,032	3,119	1,927	2,133	4.2	6,350
Delaware	548	587	336	385	4.3	4,940
D.C.	757	680	262	261	4.4	4,211
Florida	6,789	8,687	5,242	6,345	4.2	767
Georgia	4,590	5,116	3,079	3,670	4.3	3,095
Hawaii	769	912	465	544	5.6	0
Idaho	713	878	597	762	4.3	5,833
Illinois	11,114	11,265	5,940	7,127	4.9	6,298
Indiana	5,194	5,348	3,156	3,720	4.6	5,577
Iowa	2,824	2,886	1,980	2,301	5.3	6,710
Kansas	2,247	2,335	1,726	1,981	6.0	4,687
Kentucky	3,219	3,491	2,064	2,549	4.0	4,645
Louisiana	3,641	3,958	2,037	2,504	4.0	1,465
Maine	992	1,096	605	751	4.2	7,498
Maryland	3,922	4,168	2,228	2,674	4.5	4,729
Massachusetts	5,689	5,795	2,838	3,621	6.0	5,621
Michigan	9,875	9,158	5,193	6,252	4.7	7,710
Minnesota	3,805	3,998	2,451	2,897	5.2	8,958
Mississippi	2,217	2,414	1,285	1,544	3.6	2,300
Missouri	4,677	4,818	2,710	3,125	4.7	4,956
Montana	697	774	560	761	6.2	7,652
Nebraska	1,483	1,570	1,102	1,247	5.2	6,049
Nevada	489	655	431	583	3.1	6,002
New Hampshire	738	842	465	591	3.2	7,360
New Jersey	7,168	7,349	4,023	4,534	5.1	4,946
New Mexico	1,016	1,214	732	945	4.3	4,292
New York	18,237	17,874	7,273	7,851	4.9	6,221
North Carolina	2,488	2,992	3,384	4,273	3.7	3,366
North Dakota	618	659	502	595	5.0	9,044
Ohio	10,652	10,702	6,717	7,766	4.5	5,642
Oklahoma	2,559	2,846	1,959	2,361	6.1	3,692
Oregon	2,091	2,417	1,527	1,845	3.7	4,792
Pennsylvania	11,794	11,776	6,836	8,183	4.5	5,398
Rhode Island	947	930	548	690	5.1	5,972
South Carolina	2,591	2,917	1,593	1,941	3.3	2,598
South Dakota	666	692	487	585	5.3	7,838
Tennessee	3,924	4,350	2,439	3,177	4.1	3,462
Texas	11,197	13,062	7,713	10,021	4.4	2,165
Utah	1,059	1,298	774	941	4.1	5,983
Vermont	444	489	269	336	4.2	7,876
Virginia	4,648	5,200	2,944	3,330	4.3	3,714
Washington	3,409	3,689	2,358	3,048	4.3	6,010
West Virginia	1,744	1,875	902	1,170	3.1-	4,590
Wisconsin	4,418	4,684	2,479	2,734	5.6	7,444
Wyoming	332	417	292	395	6.3	7,255
U.S. Total	200,621	215,494	124,478	149,068		

---

* Source: U.S. Census Bureau (1979).

† Source: U.S. Federal Highway Administration (1978).

§ Source: U.S. Census Bureau (1979)

where

EM is the national total mobile source emissions ([g/sec) of the chemical,
A is the land area of the city (m^2),
a78 is the 1978 estimated number of automobiles in the city,
t78 is the 1978 estimated number of trucks/buses in the city,
R is the ratio of average truck emissions to the average automobile emissions,
117,147,000 is the 1978 estimated national total number of automobiles,
31,921,000 is the 1978 estimated national total number of trucks/buses.

For heating sources,

$$Q_H = \frac{EH}{A} \cdot \frac{P78 \cdot HR}{215{,}494{,}000 \cdot 4633} , \qquad (28)$$

where

EH is the national total heating source emissions (μg/sec) of the chemical,
P78 is the 1978 estimated population in the city,
HR is heating requirements (degree-days/yr),
215,494,000 is the total U.S. population (excluding military service) in 1978,
4633 is the population-weighted nationwide per-capita heating requirement (degree-days/year).

For nonheating stationary sources,

$$Q_N = \frac{EN}{A} \cdot \frac{P78}{215{,}494{,}000} \quad , \qquad (29)$$

where EN is the national total emissions from nonheating stationary area sources (μg/sec).

These three types of emissions can be summarized as the total area source emissions in the specific city. Some of the chemicals may undergo chemical decay in the ambient air. Therefore, the effective emissions rates must be estimated, taking consideration of the decay factor. The pseudo-first-order decay constants used in estimating effective emissions rates in the dispersion modeling of point source emissions were applied here also. The average time, t, that wind-blown pollutant remains within a city was estimated by assuming the average travel distance to be half the size of the city and the wind to be at its annual average speed. The average of the daytime and nighttime effective emissions rates was used as the overall effective emissions rate, Q_o, in Equation 1 in estimating the annual average concentration. The equation used in deriving the effective emissions rate is:

$$Q_o = (Q_M + Q_H + Q_W) \cdot [\exp(-Kd \frac{\sqrt{A/2}}{\mu}) + \exp(-Kn \frac{\sqrt{A/2}}{\mu})]/2 \quad , \qquad (30)$$

where Kd is the daytime chemical decay rate (sec^{-1}), Kn is the nighttime chemical decay rate (sec^{-1}), and μ is the average wind speed (m/sec).

The total dosage of ambient chemical in a specific city can be estimated by multiplying the average ambient concentration of the chemical, x, by the estimated 1978 population of that city. These exposure-dosage data for all three types of cities can be summarized at different exposure levels. The contribution of each of the three types of area emissions to the total dosage can also be estimated for each city and for all cities as a whole. The distribution of national total dosages among the three types of cities can also be estimated.

A computer program has been coded to conduct the estimation and data summarization as described above. Beryllium emitted from area sources was used as an example to exercise the program and to illustrate the nature and details of the estimated results. Table 27 lists the data input required for estimating the exposure-dosage resulting from area source emissions of beryllium. Tables 28, 29, and 30 list the annual average ambient concentration computed with the box model, the estimated 1978 population, the total resulting dosages, and the percentage contribution of total dosage by the different types of area sources for each of three types of cities. The overall national total beryllium exposure and dosage resulting from area source emissions are listed in Table 31.

This approach was used to estimate the human exposure and dosages resulting from chemical emissions from area sources in this study.

TABLE 27. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF BERYLLIUM

Parameter	Value (gm/sec)	Sources
Daytime decay rate (K_d)	0	Section 2
Nighttime decay rate (K_n)	0	Section 2
Hanna-Gifford coefficient (C)	225	EPA, 1977
Nationwide heating source emissions (E_H)	0.203	
Residential/commercial coal burning	0.058	
Residential/commercial oil burning	0.145	
Nationwide nonheating stationary source emissions (E_N)	0.538	
Coal-burning	0.396	
Oil-burning	0.142	
Nationwide mobile source emissions (E_M)	0.0693	
Ratio of truck emissions to auto emissions (R_M)	3.0	

TABLE 28. BERYLLIUM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS IN TYPE I CITIES

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION		
							HEATING	STATIONARY	MOBILE
1	1	ABIENE,TX	INNER CITY	.000078	104391	8.2	13.3	75.3	11.4
			URBAN FRINGE	.000015	1265	.0	13.3	75.3	11.4
1	2	AKRON,OH	INNER CITY	.000320	276712	88.5	29.2	63.6	7.2
			URBAN FRINGE	.000128	268619	34.3	29.2	63.6	7.2
1	3	ALBANY,GA	INNER CITY	.000144	80945	11.7	18.5	73.5	8.0
			URBAN FRINGE	.000049	4334	.2	18.5	73.5	8.0
1	4	ALBANY,NY	INNER CITY	.000348	251548	87.5	31.8	62.7	5.5
			URBAN FRINGE	.000133	225292	29.9	31.8	62.7	5.5
1	5	ALBUQUERQUE,NM	INNER CITY	.000232	291253	67.5	23.5	67.3	9.2
			URBAN FRINGE	.000118	64165	7.6	23.5	67.3	9.2
1	6	ALLENTOWN,PA	INNER CITY	.000303	212136	64.2	28.4	64.6	7.0
			URBAN FRINGE	.000164	150879	24.7	28.4	64.6	7.0
1	7	ALTOONA,PA	INNER CITY	.000340	62802	21.4	28.4	64.6	7.0
			URBAN FRINGE	.000087	18868	1.6	28.4	64.6	7.0
1	8	AMARILLO,TX	INNER CITY	.000129	142332	18.4	13.2	74.7	12.2
1	9	ANDERSON,IN	INNER CITY	.000115	72953	8.4	28.9	63.7	7.4
			URBAN FRINGE	.000080	10143	.8	28.9	63.7	7.4
1	10	ANN ARBOR,MI	INNER CITY	.000279	102979	28.8	36.2	57.7	6.1
			URBAN FRINGE	.000209	81320	17.0	36.2	57.7	6.1
1	11	APPLETON,WI	INNER CITY	.000217	60862	13.2	35.8	59.0	5.2
			URBAN FRINGE	.000155	76850	11.9	35.8	59.0	5.3
1	12	ASHEVILLE,NC	INNER CITY	.000188	69233	13.0	19.6	71.5	8.9
			URBAN FRINGE	.000066	17894	1.2	19.6	71.5	8.9
1	13	ATLANTA,GA	INNER CITY	.000270	553981	149.5	18.3	72.5	9.2
			URBAN FRINGE	.000176	753193	132.9	18.3	72.5	9.2
1	14	ATLANTIC CITY,NJ	INNER CITY	.000177	49098	8.7	26.8	66.6	6.6
			URBAN FRINGE	.000087	88301	7.7	26.8	66.6	6.6
1	15	AUGUSTA,GA	INNER CITY	.000212	66724	14.2	18.5	73.3	8.3
			URBAN FRINGE	.000128	99298	12.7	18.5	73.3	8.3
1	16	AURORA,IL	INNER CITY	.000255	131754	33.6	31.3	61.1	7.5
			URBAN FRINGE	.000128	104327	13.3	31.3	61.1	7.5
1	17	AUSTIN,TX	INNER CITY	.000223	293760	65.6	13.6	76.9	9.5
			URBAN FRINGE	.000047	14794	.7	13.6	76.9	9.5
1	18	BAKERSFIELD,CA	INNER CITY	.000160	77179	12.3	15.5	73.9	10.7
			URBAN FRINGE	.000211	119508	25.2	15.5	73.9	10.7
1	19	BALTIMORE,MD	INNER CITY	.000766	962571	737.1	26.0	67.6	6.3
			URBAN FRINGE	.000221	716298	158.0	26.0	67.6	6.3
1	20	BATON ROUGE,LA	INNER CITY	.000247	180420	44.6	9.5	79.4	11.1
			URBAN FRINGE	.000114	90762	10.3	9.5	79.4	11.1
1	21	BAY CITY,MI	INNER CITY	.000275	51025	14.0	36.1	57.4	6.5
			URBAN FRINGE	.000106	29561	3.1	36.1	57.4	6.5

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	22	BEAUMONT, TX	INNER CITY	.000104	135280	14.1	13.5	76.4	10.1
			URBAN FRINGE	.000005	449	.0	13.6	77.3	9.0
1	23	BILLINGS, MONT	INNER CITY	.000206	68381	14.1	34.5	55.4	10.1
			URBAN FRINGE	.000038	10678	.4	34.5	55.4	10.1
1	24	BILOXI, MS	INNER CITY	.000162	97165	15.7	14.4	77.1	8.5
			URBAN FRINGE	.000078	35534	2.8	14.4	77.1	8.4
1	25	BINGHAMTON, NY	INNER CITY	.000277	62846	17.4	31.7	62.6	5.7
			URBAN FRINGE	.000141	101048	14.2	31.7	62.6	5.7
1	26	BIRMINGHAM, AL	INNER CITY	.000223	325133	72.7	10.8	78.9	10.3
			URBAN FRINGE	.000113	278339	31.4	10.8	78.9	10.3
1	27	BLOOMINGTON, IL	INNER CITY	.000221	66929	14.8	31.3	61.1	7.5
			URBAN FRINGE	.000031	3131	.1	31.4	61.1	7.3
1	28	BOISE CITY, ID	INNER CITY	.000239	92343	22.0	29.7	62.6	7.7
			URBAN FRINGE	.000113	12544	1.4	29.7	62.6	7.7
1	29	BOSTON, MASS	INNER CITY	.000654	652997	427.1	29.2	63.8	6.9
			URBAN FRINGE	.000211	2049001	433.1	29.2	63.8	6.9
1	30	BOULDER, CO	INNER CITY	.000354	81019	28.7	30.0	61.3	8.7
			URBAN FRINGE	.000088	2137	.2	30.0	61.3	8.7
1	31	BRIDGEPORT, CONN	INNER CITY	.000594	161037	95.6	31.8	61.5	6.7
			URBAN FRINGE	.000154	264189	40.6	31.8	61.5	6.7
1	32	BRISTOL, CONN	INNER CITY	.000136	57079	7.7	31.8	61.5	6.7
			URBAN FRINGE	.000090	16711	1.5	31.8	61.5	6.7
1	33	BROCKTON, MASS	INNER CITY	.000179	90699	16.2	29.2	63.8	6.9
			URBAN FRINGE	.000084	60918	5.1	29.2	63.8	6.9
1	34	BROWNSVILLE, TX	INNER CITY	.000191	64892	12.4	13.8	78.3	7.9
1	35	BRYAN, TX	INNER CITY	.000107	39335	4.2	13.6	77.1	9.3
			URBAN FRINGE	.000058	20620	1.2	13.6	77.1	9.3
1	36	BUFFALO, NY	INNER CITY	.000624	453571	282.8	32.0	63.1	4.9
			URBAN FRINGE	.000240	611394	147.0	32.0	63.1	4.9
1	37	CANTON, OH	INNER CITY	.000320	110455	35.3	29.2	63.5	7.3
			URBAN FRINGE	.000147	134970	19.8	29.2	63.6	7.2
1	38	CEDAR RAPIDS, IOWA	INNER CITY	.000126	113071	14.2	32.7	59.9	7.3
			URBAN FRINGE	.000090	21835	2.0	32.7	59.9	7.3
1	39	CHAMPAIGN-URBANA, IL	INNER CITY	.000338	90591	30.6	31.6	61.7	6.7
			URBAN FRINGE	.000106	11189	1.2	31.6	61.7	6.7
1	40	CHARLESTON, SC	INNER CITY	.000273	75355	20.5	16.1	76.3	7.6
			URBAN FRINGE	.000160	181780	30.6	16.1	76.3	7.6
1	41	CHARLESTON, WV	INNER CITY	.000225	76876	17.3	25.0	67.0	8.0
			URBAN FRINGE	.000219	92628	20.3	25.0	67.0	8.0
1	42	CHARLOTTE, NC	INNER CITY	.000270	290078	78.4	19.6	71.4	9.0
			URBAN FRINGE	.000097	46076	4.5	19.6	71.4	9.0

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	43	CHATTANOOGA,TENN	INNER CITY	.000145	133613	19.3	18.4	72.9	8.7
			URBAN FRINGE	.000104	115564	12.1	18.4	72.9	8.7
1	44	CHICAGO,IL	INNER CITY	.000904	3742961	3383.1	32.1	62.6	5.3
			URBAN FRINGE	.000264	3062843	809.3	32.1	62.6	5.3
1	45	CINCINNATI,OH	INNER CITY	.000379	454674	172.3	29.4	64.0	6.6
			URBAN FRINGE	.000194	661052	128.5	29.4	64.0	6.6
1	46	CLEVELAND,OH	INNER CITY	.000643	754571	484.9	29.5	64.2	6.2
			URBAN FRINGE	.000177	1214508	215.2	29.5	64.2	6.2
1	47	COLORADO SPRINGS,CO	INNER CITY	.000184	163586	30.2	30.1	61.5	8.3
			URBAN FRINGE	.000181	84507	15.3	30.1	61.5	8.3
1	48	COLUMBIA,MO	INNER CITY	.000080	60342	4.8	26.7	66.2	7.1
1	49	COLUMBIA,SC	INNER CITY	.000209	272201	56.8	15.9	75.2	8.9
1	50	COLUMBUS,GA	INNER CITY	.000144	171757	24.7	18.6	73.8	7.6
			URBAN FRINGE	.000089	60765	5.4	18.6	73.8	7.6
1	51	COLUMBUS,OH	INNER CITY	.000268	541908	145.0	30.8	66.9	2.3
			URBAN FRINGE	.000170	251818	42.7	29.3	63.8	6.8
1	52	CORPUS CHRISTI,TX	INNER CITY	.000135	238677	32.3	13.5	76.8	9.6
			URBAN FRINGE	.000016	9600	.2	13.5	76.8	9.6
1	53	DALLAS,TX	INNER CITY	.000242	984799	238.7	13.4	75.8	10.8
			URBAN FRINGE	.000097	576859	56.2	13.4	76.0	10.6
1	54	DANBURY,CONN	INNER CITY	.000080	52238	4.2	31.8	61.5	6.7
			URBAN FRINGE	.000084	16325	1.4	31.8	61.5	6.7
1	55	DAVENPORT,IOWA	INNER CITY	.000143	199323	28.4	32.7	59.9	7.4
			URBAN FRINGE	.000113	71616	8.1	32.7	59.9	7.4
1	56	DAYTON,OH	INNER CITY	.000383	244601	93.7	29.2	63.5	7.3
			URBAN FRINGE	.000175	444559	77.8	29.2	63.5	7.3
1	57	DECATUR,IL	INNER CITY	.000170	91937	15.6	31.1	60.6	8.4
			URBAN FRINGE	.000066	9110	.6	31.1	60.6	8.4
1	58	DENVER,CO	INNER CITY	.000477	623583	297.3	30.0	61.3	8.7
			URBAN FRINGE	.000256	645337	165.0	30.0	61.3	8.7
1	59	DES MOINES,IOWA	INNER CITY	.000189	205179	38.7	32.6	59.7	7.6
			URBAN FRINGE	.000069	56260	3.9	32.6	59.7	7.6
1	60	DETROIT,MI	INNER CITY	.000839	1559528	1308.5	36.3	57.8	5.9
			URBAN FRINGE	.000316	2537666	802.7	36.3	57.8	5.9
1	61	DUBUQUE,IOWA	INNER CITY	.000188	63681	12.0	33.1	60.5	6.5
			URBAN FRINGE	.000049	3308	.2	33.0	60.5	6.5
1	62	DULUTH MN	INNER CITY	.000092	139525	12.8	39.5	54.1	6.3
			URBAN FRINGE	.000047	5844	.3	39.5	54.1	6.4
1	63	DURHAM,NC	INNER CITY	.000204	114739	23.4	19.4	70.9	9.6
			URBAN FRINGE	.000053	6436	.3	19.4	70.9	9.6

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	64	EL PASO,TX	INNER CITY	.000191	393681	75.0	13.7	77.9	8.4
1	65	ERIE,PA	INNER CITY	.000369	129022	47.6	28.4	64.6	7.0
			URBAN FRINGE	.000103	45972	4.7	28.4	64.6	7.0
1	66	EUGENE,OR	INNER CITY	.000226	88243	20.0	25.8	66.1	8.0
			URBAN FRINGE	.000171	72722	12.4	25.8	66.1	8.0
1	67	EVANSVILLE,IN	INNER CITY	.000233	142802	33.3	28.6	63.1	8.3
			URBAN FRINGE	.000036	3098	.1	28.6	63.1	8.3
1	68	FALL RIVER,MASS	INNER CITY	.000155	95190	14.8	30.1	61.8	8.2
			URBAN FRINGE	.000193	41698	8.1	30.1	61.8	8.2
1	69	FARGO,ND	INNER CITY	.000272	87240	23.7	39.0	53.5	7.5
			URBAN FRINGE	.000016	2539	.0	39.0	53.5	7.5
1	70	FAYETTEVILLE,NC	INNER CITY	.000164	64349	10.6	20.1	73.2	6.7
			URBAN FRINGE	.000171	129709	22.2	20.1	73.2	6.7
1	71	FICHBURG,MASS	INNER CITY	.000065	77703	5.1	29.2	63.8	6.9
			URBAN FRINGE	.000013	1803	.0	29.2	63.8	6.9
1	72	FLINT,MI	INNER CITY	.000381	199546	75.9	36.0	57.4	6.6
			URBAN FRINGE	.000152	141108	21.4	36.0	57.4	6.6
1	73	FORT LAUDERDALE,FL	INNER CITY	.000291	315484	92.0	5.3	84.7	10.0
			URBAN FRINGE	.000173	469911	81.5	5.3	84.7	10.0
1	74	FORT SMITH,AR	INNER CITY	.000103	71064	7.3	19.0	69.7	11.2
			URBAN FRINGE	.000055	14387	.8	19.0	69.7	11.2
1	75	FORT WAYNE,IN	INNER CITY	.000216	183007	39.6	28.9	63.7	7.4
			URBAN FRINGE	.000148	48852	7.3	28.9	63.7	7.4
1	76	FORT WORTH,TX	INNER CITY	.000142	458999	65.0	13.4	76.0	10.6
			URBAN FRINGE	.000108	330698	35.9	13.4	76.0	10.6
1	77	FRESNO,CA	INNER CITY	.000250	184271	46.1	15.5	74.2	10.3
			URBAN FRINGE	.000162	107624	17.4	15.5	74.2	10.3
1	78	GADSDEN,AL	INNER CITY	.000089	58294	5.2	10.7	77.9	11.5
			URBAN FRINGE	.000031	14916	.5	10.7	77.9	11.5
1	79	GAINSVILLE,FL	INNER CITY	.000146	82545	12.0	5.3	85.1	9.6
			URBAN FRINGE	.000074	6166	.5	5.3	85.1	9.6
1	80	GALVESTON,TX	INNER CITY	.000148	72104	10.7	13.6	77.3	9.1
1	81	GRAND RAPIDS,MI	INNER CITY	.000296	203832	60.3	35.9	57.2	6.8
			URBAN FRINGE	.000114	160116	18.3	35.9	57.2	6.8
1	82	GREAT FALLS,MT	INNER CITY	.000199	66729	13.3	34.9	56.0	9.1
			URBAN FRINGE	.000066	12008	.8	34.9	56.0	9.2
1	83	GREEN BAY,WI	INNER CITY	.000117	92963	10.9	35.7	58.9	5.4
			URBAN FRINGE	.000063	43914	2.7	35.7	58.9	5.4
1	84	GREENSBORO,NC	INNER CITY	.000217	173465	37.6	19.6	71.4	9.0
			URBAN FRINGE	.000076	9628	.7	19.6	71.4	9.0

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION		
							HEATING	STATIONARY	MOBILE
1	85	GREENSVILLE,SC	INNER CITY	.000216	68909	14.9	15.9	75.0	9.1
			URBAN FRINGE	.000157	109052	17.1	15.9	75.0	9.1
1	86	HAMILTON,OH	INNER CITY	.000228	67934	15.5	29.2	63.6	7.2
			URBAN FRINGE	.000059	23404	1.4	29.2	63.6	7.2
1	87	HARLINGEN,TX	INNER CITY	.000081	39097	3.2	13.8	78.3	7.9
			URBAN FRINGE	.000074	19777	1.5	13.8	78.3	7.9
1	88	HARRISBURY,PA	INNER CITY	.000430	67776	29.1	28.4	64.6	6.9
			URBAN FRINGE	.000156	172607	26.9	28.4	64.6	6.9
1	89	HARTFORD,CONN	INNER CITY	.000560	162551	91.0	31.8	61.5	6.7
			URBAN FRINGE	.000211	315795	66.5	31.8	61.5	6.7
1	90	HIGH POINT,NC	INNER CITY	.000156	75088	11.8	19.6	71.4	9.0
			URBAN FRINGE	.000104	36608	3.8	19.6	71.4	9.0
1	91	HONOLULU,HAWAII	INNER CITY	.000169	385202	65.0	0.	92.2	7.8
			URBAN FRINGE	.000145	139378	20.3	0.	92.2	7.8
1	92	HOUSTON,TX	INNER CITY	.000229	1437679	329.0	13.5	76.4	10.2
			URBAN FRINGE	.000206	519652	140.8	13.5	76.4	10.2
1	93	HUNTINGTON,WV	INNER CITY	.000383	111346	42.7	25.0	66.8	8.2
			URBAN FRINGE	.000169	68824	11.7	25.0	66.8	8.2
1	94	HUNSVILLE,AL	INNER CITY	.000079	149087	11.8	10.6	77.3	12.1
			URBAN FRINGE	.000030	9393	.3	10.6	77.3	12.1
1	95	INDIANAPOLIS,IN	INNER CITY	.000172	844579	145.3	29.1	64.1	6.8
1	96	JACKSON,MI	INNER CITY	.000239	46931	11.2	35.9	57.2	6.8
			URBAN FRINGE	.000082	34146	2.8	35.9	57.2	6.8
1	97	JACKSON,MS	INNER CITY	.000216	167649	36.2	14.3	76.2	9.6
			URBAN FRINGE	.000134	50187	6.7	14.3	76.2	9.6
1	98	JACKSONVILLE,FL	INNER CITY	.000123	677641	83.2	5.3	85.4	9.3
1	99	JOHNSTOWN,PA	INNER CITY	.000346	42411	14.7	28.4	64.6	7.0
			URBAN FRINGE	.000133	53588	7.1	28.4	64.6	7.0
1	100	JOLIET,IL	INNER CITY	.000250	79712	19.9	31.3	61.1	7.5
			URBAN FRINGE	.000116	77900	9.1	31.3	61.1	7.5
1	101	KALAMAZOO,MI	INNER CITY	.000218	88392	19.3	35.9	57.2	6.8
			URBAN FRINGE	.000093	68540	6.4	35.9	57.2	6.8
1	102	KANSASCITY,MO	INNER CITY	.000138	695752	95.8	26.6	65.8	7.6
			URBAN FRINGE	.000235	439250	103.1	26.6	65.8	7.6
1	103	KENOSHA,WI	INNER CITY	.000280	83562	23.4	35.7	58.9	5.4
			URBAN FRINGE	.000053	5772	.3	35.7	58.9	5.4
1	104	KNOXVILLE,TENN	INNER CITY	.000164	193540	31.8	20.1	71.2	8.7
			URBAN FRINGE	.000098	17642	1.7	20.1	71.2	8.7
1	105	LA CROSSE,WI	INNER CITY	.000166	54232	9.0	35.7	58.8	5.5
			URBAN FRINGE	.000064	12955	.8	35.7	58.8	5.5

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	106	LAFAYETTE,LA	INNER CITY	.000190	74990	14.2	9.5	79.4	11.1
			URBAN FRINGE	.000089	10392	.9	9.5	79.4	11.1
1	107	LAFAYETTE,IN	INNER CITY	.000257	46287	11.9	29.2	64.2	6.6
			URBAN FRINGE	.000168	35174	5.9	29.2	64.2	6.6
1	108	LAKE CHARLES,LA	INNER CITY	.000190	84788	16.1	9.5	79.4	11.1
			URBAN FRINGE	.000048	11155	.5	9.5	79.4	11.1
1	109	LANCASTER,PA	INNER CITY	.000382	57501	22.0	28.4	64.7	6.9
			URBAN FRINGE	.000108	59417	6.4	28.4	64.7	6.9
1	110	LANSING,MI	INNER CITY	.000255	135835	34.6	36.0	57.4	6.6
			URBAN FRINGE	.000163	101001	16.5	36.0	57.4	6.6
1	111	LAREDO,TX	INNER CITY	.000176	80419	14.2	14.1	80.1	5.8
			URBAN FRINGE	.000032	1469	.0	14.1	80.1	5.8
1	112	LAS VEGAS,NV	INNER CITY	.000312	168292	52.6	30.1	61.3	8.6
			URBAN FRINGE	.000213	148734	31.7	30.1	61.3	8.6
1	113	LAWRENCE,MASS	INNER CITY	.000133	115153	15.3	29.2	63.8	6.9
			URBAN FRINGE	.000091	88858	8.1	29.2	63.8	6.9
1	114	LAWTON,OK	INNER CITY	.000106	82996	8.8	20.7	68.9	10.4
			URBAN FRINGE	.000066	23421	1.5	20.7	68.9	10.4
1	115	LEWISTON,MAINE	INNER CITY	.000095	46159	4.4	34.9	57.2	7.9
			URBAN FRINGE	.000055	25889	1.4	34.9	57.2	7.9
1	116	LEXINGTON,KY	INNER CITY	.000312	117274	36.6	25.0	66.1	8.8
			URBAN FRINGE	.000193	55744	10.8	25.0	66.1	8.8
1	117	LIMA,OH	INNER CITY	.000240	53733	12.9	28.9	63.0	8.1
			URBAN FRINGE	.000060	16891	1.0	28.9	63.0	8.1
1	118	LINCOLN,NEB	INNER CITY	.000178	158289	28.1	30.8	62.5	6.7
			URBAN FRINGE	.000059	4155	.2	30.8	62.5	6.7
1	119	LITTLE ROCK,AR	INNER CITY	.000223	169189	37.7	19.4	71.2	9.4
			URBAN FRINGE	.000116	82715	9.6	19.4	71.2	9.4
1	120	LORAIN,OH	INNER CITY	.000200	132768	26.6	29.2	63.6	7.2
			URBAN FRINGE	.000059	60399	3.5	29.2	63.6	7.2
1	121	LOS ANGELES,CA	INNER CITY	.000526	4019117	2115.6	15.9	75.8	8.3
			URBAN FRINGE	.000441	5252951	2314.1	15.9	75.8	8.3
1	122	LOUISVILLE,KY	INNER CITY	.000385	372169	143.1	28.9	63.7	7.4
			URBAN FRINGE	.000180	389148	70.2	28.9	63.7	7.4
1	123	LOWELL,MASS	INNER CITY	.000279	96007	26.8	29.2	63.8	6.9
			URBAN FRINGE	.000096	100314	9.6	29.2	63.8	6.9
1	124	LUBBOCK,TX	INNER CITY	.000127	175141	22.2	13.4	76.2	10.3
1	125	LYNCHBURG,VA	INNER CITY	.000128	60505	7.8	21.5	71.0	7.5
			URBAN FRINGE	.000076	18749	1.4	21.5	71.0	7.5
1	126	MACON,GA	INNER CITY	.000156	136452	21.3	18.4	73.0	8.5
			URBAN FRINGE	.000118	6288	.7	18.4	73.0	8.5

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	127	MADISON,WI	INNER CITY	.000203	183672	37.3	35.7	58.9	5.4
			URBAN FRINGE	.000080	34154	2.7	35.7	58.9	5.4
1	128	MANCHESTER,NH	INNER CITY	.000204	100120	20.4	34.6	58.1	7.1
			URBAN FRINGE	.000092	8426	.8	34.8	58.1	7.1
1	129	MANSFIELD,OH	INNER CITY	.000131	55259	7.3	28.9	62.8	8.3
			URBAN FRINGE	.000074	22704	1.7	28.9	62.8	8.3
1	130	MCALLEN,TX	INNER CITY	.000143	43904	6.3	13.7	78.0	8.3
			URBAN FRINGE	.000147	62416	9.2	13.7	78.0	8.3
1	131	MEMPHIS,MS	INNER CITY	.000280	722976	202.1	14.4	77.1	8.4
1	132	MERIDEN,CONN	INNER CITY	.000151	57564	8.7	31.8	61.5	6.7
			URBAN FRINGE	.000063	43714	2.7	31.8	61.5	6.7
1	133	MIAMI,FL	INNER CITY	.000590	428751	253.1	5.4	86.0	8.7
			URBAN FRINGE	.000299	1131901	338.0	5.4	86.6	8.0
1	134	MIDLAND,TX	INNER CITY	.000120	69630	8.3	13.2	75.0	11.8
			URBAN FRINGE	.000011	795	.0	13.2	75.0	11.7
1	135	MILLWAKEE,WI	INNER CITY	.000464	760300	332.7	36.0	59.3	4.7
			URBAN FRINGE	.000107	567564	61.0	36.0	59.3	4.7
1	136	MINNEAPOLIS,MN	INNER CITY	.000503	782074	393.4	39.7	54.4	5.9
			URBAN FRINGE	.000141	1008800	141.9	39.7	54.4	5.9
1	137	MOBILE,AL	INNER CITY	.000101	205432	20.7	10.9	79.3	9.9
			URBAN FRINGE	.000074	73344	5.4	10.9	79.3	9.9
1	138	MODESTO,CA	INNER CITY	.000343	68516	23.5	15.4	73.4	11.2
			URBAN FRINGE	.000108	49289	5.3	15.4	73.4	11.2
1	139	MONROE,LA	INNER CITY	.000142	61282	8.7	9.5	79.4	11.1
			URBAN FRINGE	.000104	37169	3.9	9.5	79.4	11.1
1	140	MONTGOMERY,AL	INNER CITY	.003453	446952	1543.4	11.7	85.0	3.4
			URBAN FRINGE	.000049	5960	.3	10.8	79.1	10.1
1	141	MUNCIE,IN	INNER CITY	.000204	71181	28.2	29.0	63.8	7.2
			URBAN FRINGE	.000091	21926	2.0	29.0	63.8	7.2
1	142	MUSKEGON,MI	INNER CITY	.000197	46854	9.1	36.1	57.5	6.4
			URBAN FRINGE	.000103	63032	6.5	36.1	57.5	6.4
1	143	NASHUA,NH	INNER CITY	.000182	63070	11.5	34.8	58.0	7.2
			URBAN FRINGE	.000150	5865	.9	34.8	58.1	7.1
1	144	NASHVILLE,TENN	INNER CITY	.000114	497128	56.8	20.0	70.9	9.1
1	145	NEW BEDFORD,MASS	INNER CITY	.000220	103655	22.8	29.2	63.8	6.9
			URBAN FRINGE	.000089	32502	2.9	29.2	63.8	6.9
1	146	NEW BRITAIN,CONN	INNER CITY	.000374	85835	32.1	31.8	61.5	6.7
			URBAN FRINGE	.000121	49282	5.9	31.8	61.5	6.7
1	147	NEW HAVEN,CONN	INNER CITY	.000465	141666	65.9	31.8	61.5	6.7
			URBAN FRINGE	.000180	216669	38.9	31.8	61.5	6.7

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION		
							HEATING	STATIONARY	MOBILE
1	148	NEW ORLEANS,LA	INNER CITY	.000380	1045459	397.2	9.5	79.4	11.1
1	149	NEW YORK,NY	INNER CITY	.001735	8644589	14995.4	32.8	64.7	2.5
			URBAN FRINGE	.000317	7239660	2294.0	32.8	64.7	2.5
1	150	NEWPORT,VA	INNER CITY	.000150	289709	43.4	21.8	71.9	6.3
			URBAN FRINGE	.000028	10412	.3	21.8	71.9	6.3
1	151	NORFORK,VA	INNER CITY	.000349	468664	163.7	21.8	71.9	6.3
			URBAN FRINGE	.000088	278957	24.6	21.8	71.9	6.3
1	152	NORWALK,CONN	INNER CITY	.000229	81464	18.6	31.8	61.5	6.7
			URBAN FRINGE	.000086	28304	2.4	31.8	61.5	6.7
1	153	ODESSA,TX	INNER CITY	.000237	91435	21.6	13.2	74.6	12.3
			URBAN FRINGE	.000024	3808	.1	13.2	74.6	12.3
1	154	OGDEN,UT	INNER CITY	.000253	85166	21.5	30.2	62.0	7.8
			URBAN FRINGE	.000166	98351	16.3	30.2	62.0	7.8
1	155	OKLAHOMA CITY,OK	INNER CITY	.000103	644813	66.2	20.7	68.9	10.4
1	156	OMAHA,IOWA	INNER CITY	.000273	355006	97.0	33.0	60.4	6.7
			URBAN FRINGE	.000116	146544	17.0	33.0	60.4	6.7
1	157	ORLANDO,FL	INNER CITY	.000217	126632	27.4	5.2	83.9	10.8
			URBAN FRINGE	.000141	264249	37.1	5.2	83.9	10.8
1	158	OSHKOSH,KY	INNER CITY	.000267	60167	16.1	24.7	65.2	10.2
1	159	OWENSBORO,KY	INNER CITY	.000349	54568	19.1	24.8	65.7	9.5
			URBAN FRINGE	.000042	3053	.1	24.8	65.7	9.5
1	160	OXNARD,CA	INNER CITY	.000153	180720	27.7	15.8	75.5	8.7
			URBAN FRINGE	.000121	90908	11.0	15.8	75.5	8.7
1	161	PENSACOLA,FL	INNER CITY	.000144	76225	11.0	5.4	85.7	8.9
			URBAN FRINGE	.000158	136975	21.7	5.4	85.7	8.9
1	162	PEORIA,IL	INNER CITY	.000197	128688	25.4	31.3	61.1	7.6
			URBAN FRINGE	.000109	121790	13.2	31.3	61.1	7.6
1	163	PETERSBURG,VA	INNER CITY	.000230	40390	9.3	21.7	71.8	6.5
			URB FRINGE	.000116	72175	8.4	21.7	71.8	6.5
1	164	PHILADELPHIA,PA	INNER CITY	.000929	1997813	1856.6	26.8	66.5	6.7
			URBAN FRINGE	.000248	2124788	527.3	26.8	66.5	6.7
1	165	PHOENIX,ARIZ	INNER CITY	.000289	776670	224.2	10.1	80.0	9.8
			URBAN FRINGE	.000231	376259	86.8	10.1	80.0	9.8
1	166	PINE BLUFF,AR	INNER CITY	.000224	64833	14.6	19.7	72.0	8.3
			URBAN FRINGE	.000040	4087	.2	19.7	72.0	8.3
1	167	PITTSBURG,PA	INNER CITY	.000584	519373	303.3	28.4	64.5	7.1
			URBAN FRINGE	.000201	1323851	266.6	28.4	64.5	7.1
1	168	PITTSFIELD,MASS	INNER CITY	.003703	58188	215.5	29.2	63.8	6.9
			URBAN FRINGE	.000054	5855	.3	29.2	63.8	6.9
1	169	PORT AUTHER,TX	INNER CITY	.000073	66937	4.9	13.5	76.4	10.1
			URBAN FRINGE	.000134	68936	9.3	13.5	76.4	10.1

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION		
							HEATING	STATIONARY	MOBILE
1	170	PORTLAND, MAINE	INNER CITY	.000223	71942	16.1	34.9	57.2	7.9
			URBAN FRINGE	.000095	45032	4.3	34.9	57.2	7.9
1	171	PORTLAND, OR	INNER CITY	.000340	413242	140.5	29.9	61.0	9.1
			URBAN FRINGE	.000215	479439	103.2	29.9	61.0	9.1
1	172	PROVIDENCE, RI	INNER CITY	.000314	333723	104.8	30.1	61.8	8.2
			URBAN FRINGE	.000163	447310	73.1	30.1	61.8	8.2
1	173	PROVO, UT	INNER CITY	.000177	96684	17.1	30.3	62.3	7.4
			URBAN FRINGE	.000069	30921	2.1	30.3	62.3	7.4
1	174	PUEBLO, CO	INNER CITY	.000319	118074	37.7	30.0	61.2	8.9
			URBAN FRINGE	.000041	7084	.3	30.0	61.2	8.9
1	175	RACINE, WI	INNER CITY	.000350	100924	35.4	35.8	59.0	5.2
			URBAN FRINGE	.000073	23552	1.7	35.8	59.0	5.2
1	176	RALEIGH, NC	INNER CITY	.000217	145665	31.6	19.4	70.9	9.6
			URBAN FRINGE	.000090	37473	3.4	19.4	70.9	9.6
1	177	READING, PA	INNER CITY	.000437	87487	38.2	28.4	64.6	7.0
			URBAN FRINGE	.000149	80188	11.9	28.4	64.6	7.0
1	178	RENO, NEV	INNER CITY	.000293	97597	28.6	29.7	60.5	9.9
			URBAN FRINGE	.000357	35929	12.8	29.7	60.5	9.9
1	179	RICHMOND, VA	INNER CITY	.000274	279266	76.6	21.5	71.1	7.4
			URBAN FRINGE	.000135	186768	25.3	21.5	71.1	7.4
1	180	ROANOKE, VA	INNER CITY	.000209	103054	21.6	21.3	70.4	8.3
			URBAN FRINGE	.000104	72166	7.5	21.3	70.4	8.3
1	181	ROCHESTER, MN	INNER CITY	.000225	56493	12.7	39.5	54.1	6.4
			URBAN FRINGE	.000076	2981	.2	39.5	54.1	6.4
1	182	ROCHESTER, NY	INNER CITY	.000446	290336	129.5	31.7	62.6	5.7
			URBAN FRINGE	.000177	299054	52.9	31.7	62.6	5.7
1	183	ROCKFORD, IL	INNER CITY	.000247	149204	36.8	31.5	61.4	7.2
			URBAN FRINGE	.000122	59678	7.3	31.5	61.4	7.2
1	184	SACRAMENTO, CA	INNER CITY	.000187	282409	52.9	15.7	74.8	9.5
			URBAN FRINGE	.000185	421196	77.9	15.7	74.8	9.5
1	185	SAGINAW, MI	INNER CITY	.000316	94747	29.9	36.1	57.5	6.4
			URBAN FRINGE	.000131	57509	7.5	36.1	57.5	6.4
1	186	ST. JOSEPH, MO	INNER CITY	.000141	75187	10.6	26.5	65.6	7.9
			URBAN FRINGE	.000054	4363	.2	26.5	65.6	7.9
1	187	ST. LOUIS, MO	INNER CITY	.000610	640994	391.1	26.9	66.6	6.5
			URBAN FRINGE	.000239	1298715	310.7	26.9	66.6	6.5
1	188	ST. PETERSBURG, FL	INNER CITY	.000253	276472	69.9	5.3	85.0	9.7
			URBAN FRINGE	.000186	357117	66.4	5.3	85.0	9.7
1	189	SALEM, OR	INNER CITY	.000213	78889	16.8	25.8	66.2	8.6
			URBAN FRINGE	.000141	20657	4.0	25.8	66.2	8.0

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	190	SALINAS,CA	INNER CITY	.000237	65389	15.5	15.8	75.6	8.6
			URBAN FRINGE	.000087	3952	.3	15.8	75.6	8.6
1	191	SALT LAKE CITY,UT	INNER CITY	.000258	215491	55.5	30.2	62.0	7.8
			URBAN FRINGE	.000232	372030	86.3	30.2	62.0	7.8
1	192	SANANGELO,TX	INNER CITY	.000112	74524	8.4	13.2	75.0	11.7
1	193	SAN ANTONIO,TX	INNER CITY	.000254	763268	193.6	13.7	77.5	8.8
			URBAN FRINGE	.000178	137915	24.6	13.7	77.5	8.8
1	194	SAN BERNARDINO,CA	INNER CITY	.000151	271084	41.0	15.5	73.9	10.7
			URBAN FRINGE	.000134	376859	50.5	15.5	73.9	10.7
1	195	SAN DIEGO,CA	INNER CITY	.000175	773368	135.3	15.8	75.6	8.6
			URBAN FRINGE	.000511	557080	284.7	15.8	75.6	8.6
1	196	SAN FRANCISCO,CA	INNER CITY	.000700	1269817	889.0	15.9	75.9	8.2
			URBAN FRINGE	.000277	2047469	567.9	15.9	75.9	8.2
1	197	SAN JOSE,CA	INNER CITY	.000236	495735	116.9	15.8	75.4	8.8
			URBAN FRINGE	.000296	642583	190.3	15.8	75.4	8.8
1	198	SANTA BARBARA,CA	INNER CITY	.000190	77952	14.8	15.8	75.4	8.8
			URBAN FRINGE	.000205	66130	13.5	15.8	75.4	8.8
1	199	SANTA ROSA,CA	INNER CITY	.000144	55371	8.0	15.4	73.6	11.0
			URBAN FRINGE	.000080	27989	2.2	15.4	73.6	11.0
1	200	SAVANNAH,GA	INNER CITY	.000253	131905	33.4	18.5	73.5	8.0
			URBAN FRINGE	.000074	50612	3.7	18.5	73.5	8.0
1	201	SCRANTON,PA	INNER CITY	.000230	103336	23.8	27.9	63.4	8.8
			URBAN FRINGE	.000091	100557	9.1	27.9	63.4	8.8
1	202	SEASIDE,CA	INNER CITY	.000203	69114	14.1	15.8	75.6	8.6
			URBAN FRINGE	.000217	34454	7.5	15.8	75.6	8.6
1	203	SEATTLE,WA	INNER CITY	.000420	632640	265.6	30.1	61.4	8.5
			URBAN FRINGE	.000200	707159	141.2	30.1	61.4	8.5
1	204	SHERMAN,TX	INNER CITY	.000085	33922	2.9	13.1	74.2	12.7
			URBAN FRINGE	.000091	30638	2.8	13.1	74.2	12.7
1	205	SHREVEPORT,LA	INNER CITY	.000201	198150	39.8	9.5	79.4	11.1
			URBAN FRINGE	.000084	56836	4.8	9.5	79.4	11.1
1	206	SIMI VALLEY,CA	INNER CITY	.000142	62925	8.9	15.8	75.5	8.7
			URBAN FRINGE	.000006	288	.0	15.8	75.5	8.7
1	207	SIOUX CITY,IOWA	INNER CITY	.000096	87811	8.4	32.6	59.6	7.8
			URBAN FRINGE	.000058	10231	.6	32.6	59.6	7.8
1	208	SIOUX FALLS,SD	INNER CITY	.000213	7530	1.6	20.8	32.6	46.7
			URBAN FRINGE	.000055	2761	.2	35.8	56.1	8.0
1	209	SOUTH BEND,IN	INNER CITY	.000250	129531	32.4	29.1	64.0	6.9
			URBAN FRINGE	.000144	167596	24.1	29.1	64.0	6.9
1	210	SPOKANE,WA	INNER CITY	.000249	184521	45.9	29.8	60.9	9.4
			URBAN FRINGE	.000149	63958	9.5	29.8	60.9	9.4

TABLE 28 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
1	211	SPRINGFIELD, IL	INNER CITY	.000202	92851	18.8	31.2	60.8	8.0
			URBAN FRINGE	.000162	29583	4.8	31.2	60.8	8.0
1	212	SPRINGFIELD, MO	INNER CITY	.000120	123616	14.9	26.2	64.8	9.0
			URBAN FRINGE	.000035	1381	.0	26.2	64.8	9.0
1	213	SPRINGFIELD, OH	INNER CITY	.000267	82234	22.0	29.1	63.3	7.6
			URBAN FRINGE	.000071	11858	.8	29.1	63.3	7.6
1	214	SPRINGFIELD, MASS	INNER CITY	.000165	285822	47.2	29.2	63.8	6.9
			URBAN FRINGE	.000084	238068	20.0	29.2	63.8	6.9
1	215	STAMFORD, CONN	INNER CITY	.000194	111976	21.8	31.8	61.5	6.7
			URBAN FRINGE	.000159	78227	12.4	31.8	61.5	6.7
1	216	STEUBENVILLE, OH	INNER CITY	.000123	58300	7.1	29.3	63.8	6.8
			URBAN FRINGE	.000121	27592	3.3	29.3	63.8	6.8
1	217	STOCKTON, CA	INNER CITY	.000217	119307	25.9	15.5	74.3	10.2
			URBAN FRINGE	.000174	58748	10.2	15.5	74.3	10.2
1	218	SYRACUSE, NY	INNER CITY	.000404	193343	78.2	31.7	62.6	5.7
			URBAN FRINGE	.000153	175338	26.8	31.7	62.6	5.7
1	219	TACOMA, WA	INNER CITY	.000236	167249	39.5	30.1	61.5	8.5
			URBAN FRINGE	.000170	192583	32.8	30.1	61.5	8.5
1	220	TALLAHASSEE, FL	INNER CITY	.000161	92044	14.8	5.4	85.9	8.7
			URBAN FRINGE	.000070	7573	.5	5.4	85.9	8.7
1	221	TAMPA, FL	INNER CITY	.000225	355382	79.9	5.3	85.0	9.7
			URBAN FRINGE	.000124	116448	14.5	5.3	85.0	9.7
1	222	TERRE HAUTE, IN	INNER CITY	.000156	72400	11.3	28.8	63.3	7.9
			URBAN FRINGE	.000086	10906	.9	28.8	63.3	7.9
1	223	TEXARKANA, TX	INNER CITY	.000102	35576	3.6	13.3	75.3	11.4
			URBAN FRINGE	.000102	32748	3.3	13.3	75.3	11.4
1	224	TEXAS CITY, TX	INNER CITY	.000066	98054	6.4	13.6	77.3	9.1
1	225	TOLEDO, OH	INNER CITY	.000342	396260	135.7	36.0	57.3	6.8
			URBAN FRINGE	.000089	107083	9.5	36.0	57.3	6.8
1	226	TOPEKA, KANS	INNER CITY	.000124	129830	16.2	25.0	65.4	9.6
			URBAN FRINGE	.000047	7450	.4	25.0	65.4	9.6
1	227	TRENTON, NJ	INNER CITY	.000599	107218	64.2	26.8	66.6	6.6
			URBAN FRINGE	.000163	173851	28.4	26.8	66.6	6.6
1	228	TUCSON, ARIZ	INNER CITY	.000351	351121	123.2	10.1	80.1	9.7
			URBAN FRINGE	.000115	41732	4.8	10.1	80.1	9.7
1	229	TULSA, OK	INNER CITY	.000107	369012	39.3	20.7	68.7	10.6
			URBAN FRINGE	.000187	44151	8.2	20.7	68.7	10.6
1	230	TUSCALOOSA, AL	INNER CITY	.000123	71120	8.7	10.9	79.7	9.3
			URBAN FRINGE	.000058	21736	1.3	10.9	79.7	9.3
1	231	TYLER, TX	INNER CITY	.000141	67392	9.5	13.3	75.4	11.3
			URBAN FRINGE	.000044	2345	.1	13.3	75.4	11.3

TABLE 28 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
I	232	UTICA,NY	INNER CITY	.000285	89829	25.6	31.8	62.8	5.4
			URBAN FRINGE	.000088	86935	7.6	31.8	62.8	5.4
I	233	VINELAND,NJ	INNER CITY	.000039	48846	1.9	26.8	66.6	6.6
			URBAN FRINGE	.000079	26590	2.1	26.8	66.6	6.6
I	234	WACO,TX	INNER CITY	.000103	111203	11.4	13.4	75.9	10.7
			URBAN FRINGE	.000044	27434	1.2	13.4	75.9	10.7
I	235	WASHINGTON,DC	INNER CITY	.000643	679565	436.7	24.4	71.1	4.5
			URBAN FRINGE	.000265	1549513	410.5	24.4	71.1	4.5
I	236	WATERBURY,CONN	INNER CITY	.000256	111132	28.4	31.8	61.5	6.7
			URBAN FRINGE	.000101	50357	5.1	31.8	61.5	6.7
I	237	WATERLOO,IOWA	INNER CITY	.000075	77237	5.8	32.7	59.8	7.5
			URBAN FRINGE	.000179	38121	6.8	32.7	59.8	7.5
I	238	WEST PALM BEACH,FL	INNER CITY	.000093	73355	6.8	5.3	84.7	10.0
			URBAN FRINGE	.000165	294599	48.6	5.3	84.7	10.0
I	239	WHEELING,WV	INNER CITY	.000282	51906	14.6	25.2	67.5	7.2
			URBAN FRINGE	.000239	48018	11.5	25.2	67.5	7.2
I	240	WICHITA,KANS	INNER CITY	.000164	287535	47.0	24.9	65.2	9.9
			URBAN FRINGE	.000058	26638	1.6	24.9	65.2	9.9
I	241	WICHITA FALLS,TX	INNER CITY	.000142	113814	16.1	13.3	75.4	11.3
I	242	WILKES,PA	INNER CITY	.000424	58727	24.9	27.9	63.4	8.8
			URBAN FRINGE	.000141	163762	23.0	27.9	63.4	8.8
I	243	WILMINGTON,DEL	INNER CITY	.000352	86106	30.3	26.5	65.8	7.7
			URBAN FRINGE	.000218	311582	67.9	26.5	65.8	7.7
I	244	WILMINGTON,NC	INNER CITY	.000187	55521	10.4	19.6	71.5	8.8
			URBAN FRINGE	.000067	13800	.9	19.6	71.5	8.8
I	245	WINSTON,NC	INNER CITY	.000193	159823	30.8	19.6	71.4	9.0
			URBAN FRINGE	.000067	11644	.8	19.6	71.4	9.0
I	246	WORCESTER,MASS	INNER CITY	.000216	179893	38.8	29.2	63.8	6.9
			URBAN FRINGE	.000071	72132	5.2	29.2	63.8	6.9
I	247	YORK,PA	INNER CITY	.000437	50278	22.0	28.4	64.6	6.9
			URBAN FRINGE	.000132	72659	9.6	28.4	64.6	6.9
I	248	YOUNGSTOWN,OH	INNER CITY	.000274	204127	56.0	29.2	63.6	7.1
			URBAN FRINGE	.000153	193268	29.6	29.2	63.6	7.1

Source: Systems Applications, Incorporated computations.

TABLE 29. BERYLLIUM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS IN TYPE II CITIES

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
2	1	ANNISTON,AL	.000095	34069	3.2	10.8	78.9	10.3
2	2	BESSEMER,AL	.000110	36206	4.0	10.9	79.5	9.6
2	3	DECATUR,AL	.000075	41137	3.1	10.6	77.5	11.8
2	4	DOTHAN,AL	.000042	39719	1.7	10.6	77.5	11.8
2	5	FLORENCE,AL	.000089	58294	5.2	10.7	77.8	11.6
2	6	PHENIX CITY,AL	.000064	27336	1.8	10.6	77.5	11.8
2	7	SELMA,AL	.000100	29604	3.0	10.6	77.5	11.8
2	8	ANCHORAGE,AL	.000306	67419	20.6	39.1	53.3	7.7
2	9	FLAGSTAFF,AR	.000042	34676	1.5	10.2	80.4	9.4
2	10	YUMA,AR	.000292	38736	11.3	10.2	80.4	9.4
2	11	EL DORADO,AR	.000102	28609	2.9	19.1	70.1	10.8
2	12	FAYETTEVILLE,AR	.000111	34670	3.9	19.2	70.2	10.6
2	13	HOTSPRING,AR	.000103	40318	4.2	19.1	70.1	10.8
2	14	JONESBORO,AR	.000141	30581	4.3	19.1	70.1	10.8
2	15	WEST MEMPHIS,AR	.000179	29340	5.2	19.1	70.1	10.8
2	16	ANTIOCH,CA	.000189	31092	5.9	15.8	75.5	8.7
2	17	CONCORD,CA	.000192	94446	18.1	15.8	75.5	8.7
2	18	CORONA,CA	.000069	30538	2.1	15.7	75.0	9.4
2	19	FAIRFIELD,CA	.000156	49013	7.6	15.8	75.8	8.4
2	20	LANCASTER,CA	.000121	36161	4.4	15.9	75.8	8.3
2	21	LIVERMORE,CA	.000167	41860	7.0	15.9	75.9	8.2
2	22	LODI,CA	.000204	31854	6.5	15.5	74.3	10.2
2	23	LOMPAC,CA	.000132	20111	3.7	15.8	75.4	8.8
2	24	NAPA,CA	.000149	39944	6.0	15.6	74.5	10.0
2	25	NEWARK,CA	.000163	30144	4.9	15.9	75.9	8.2
2	26	NOVATO,CA	.000083	34232	2.9	15.8	75.7	8.5
2	27	OCEANSIDE,CA	.000070	44955	3.1	15.8	75.6	8.6
2	28	REDLANDS,CA	.000098	40428	4.0	15.3	73.1	11.6
2	29	REDWOOD CITY,CA	.000154	61662	9.5	15.7	75.1	9.2
2	30	SAN LUIS OBISPO,CA	.000159	31127	5.0	15.6	74.8	9.6
2	31	SAN RAFAEL,CA	.000147	43243	6.4	15.8	75.7	8.5
2	32	SANTA CRUZ,CA	.000142	35612	5.1	15.5	73.9	10.6
2	33	SANTA MARIA,CA	.000124	36359	4.5	15.8	75.4	8.8
2	34	VISALIA,CA	.000118	30274	3.6	15.6	74.8	9.6
2	35	WALNUT CREEK,CA	.000147	44224	6.5	15.8	75.5	8.7
2	36	FORT COLLINS,CO	.000274	52544	14.4	29.6	60.4	10.1
2	37	GREELEY,CO	.000330	47133	15.6	29.6	60.4	10.1
2	38	MIDDLETOWN,CON	.000058	37961	2.2	31.8	61.5	6.7
2	39	MILFORD,CON	.000143	52317	7.6	31.8	61.5	6.7
2	40	NEW LONDON,CON	.000280	32512	9.1	31.8	61.5	6.7

TABLE 29 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
2	41	NORWICH,CON	.000103	42621	4.4	31.8	61.5	6.7
2	42	SHELTON,CON	.000059	27974	1.7	31.8	61.5	6.7
2	43	TORRINGTON,CON	.000055	32868	1.8	31.8	61.5	6.7
2	44	DAYTONA BEACH,FL	.000113	57999	6.5	5.4	87.1	7.5
2	45	FORTMYERS,FL	.000124	34997	4.3	5.2	83.9	10.9
2	46	FORT PIERCE,FL	.000147	38039	5.6	5.4	85.8	8.8
2	47	KEY WEST,FL	.000313	34961	10.9	5.3	84.9	9.8
2	48	LAKELAND,FL	.000180	53166	9.6	5.2	83.7	11.0
2	49	MELBOURNE,FL	.000092	51582	4.7	5.3	85.2	9.5
2	50	MERRITT ISLAND,FL	.000100	37405	3.7	5.3	85.2	9.5
2	51	PANAMA CITY,FL	.000127	41106	5.2	5.3	84.9	9.8
2	52	POMPANO BEACH,FL	.000175	48253	8.5	5.3	84.7	10.0
2	53	SARASOTA,FL	.000160	51486	8.2	5.2	83.3	11.5
2	54	TITUSVILLE,FL	.000111	39046	4.3	5.3	85.2	9.5
2	55	ATHENS,GE	.000165	49423	8.1	18.2	72.1	9.7
2	56	ROME,GE	.000123	34280	4.2	18.2	72.1	9.7
2	57	VALDOSTA,GE	.000154	36226	5.6	18.2	72.1	9.7
2	58	WARNER ROBINS,GE	.000117	37260	4.4	18.4	72.8	8.8
2	59	HILO,HA	.000020	31260	.6	0.	91.5	8.5
2	60	IDAHO FALLS, ID	.000264	44055	11.6	28.5	59.9	11.6
2	61	LEWISTON, ID	.000127	32100	4.1	28.4	59.8	11.8
2	62	POCATELLO, ID	.000213	49300	10.5	28.5	59.9	11.6
2	63	ALTON, IL	.000180	40239	7.2	31.3	61.1	7.5
2	64	BELLEVILLE, IL	.000214	42477	9.1	31.3	61.1	7.5
2	65	DANVILLE, IL	.000168	43270	7.3	31.3	61.1	7.5
2	66	DE KALB, IL	.000417	33375	13.9	31.3	61.1	7.5
2	67	EAST ST. LOUIS, IL	.000259	70097	18.3	31.3	61.1	7.5
2	68	FREEPORT, IL	.000161	28112	4.5	31.3	61.1	7.5
2	69	GALESBURG, IL	.000150	36783	5.5	31.3	61.1	7.5
2	70	KANKAKEE, IL	.000194	31305	6.1	31.3	61.1	7.5
2	71	PEKIN, IL	.000167	31722	5.3	31.5	61.3	7.2
2	72	QUINCY, IL	.000192	45903	8.8	31.3	61.1	7.5
2	73	BLOOMINGTON, IN	.000258	44044	11.4	28.5	62.7	8.9
2	74	COLUMBUS, IN	.000160	28104	4.5	28.5	62.7	8.9
2	75	ELKHART, IN	.000153	44886	6.9	28.5	62.7	8.9
2	76	KOKOMO, IN	.000246	45347	11.1	28.5	62.7	8.9
2	77	MARION, IN	.000214	41017	8.8	28.5	62.7	8.9
2	78	MICHIGAN, IN	.000108	40437	4.4	28.5	62.7	8.9
2	79	NEW ALBANY, IN	.000179	39540	7.1	28.5	62.7	8.9
2	80	RICHMOND, IN	.000173	45314	7.9	28.5	62.7	8.9

TABLE 29 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
2	81	AMES, IA	.000122	40370	5.0	31.8	58.1	10.1
2	82	BURLINGTON, IA	.000125	33156	4.1	31.8	58.1	10.1
2	83	CLINTON, IA	.000059	35481	2.1	31.8	58.1	10.1
2	84	FORT DODGE, IA	.000110	31949	3.5	31.8	58.1	10.1
2	85	IOWA CITY, IA	.000118	47878	5.7	31.8	58.1	10.1
2	86	MARSHALLTOWN, IA	.000092	26944	2.5	31.8	58.1	10.1
2	87	MASON CITY, IA	.000103	31160	3.2	31.8	58.1	10.1
2	88	OTTUMWA, IA	.000124	30346	3.8	31.8	58.1	10.1
2	89	HUTCHINSON, KA	.000114	38329	4.4	24.3	63.6	12.1
2	90	LAWRENCE, KA	.000116	47365	5.5	24.3	63.6	12.1
2	91	LEAVENWORTH, KA	.000111	26131	2.9	24.3	63.6	12.1
2	92	MANHATTAN, KA	.000143	28634	4.1	24.3	63.6	12.1
2	93	OVERLAND PARK, KA	.000081	79070	6.4	24.3	63.6	12.1
2	94	PRAIRIE VILLAGE, KA	.000168	29204	4.9	24.3	63.6	12.1
2	95	SALINA, KA	.000101	39191	4.0	24.3	63.6	12.1
2	96	BOWLING GREEN, KE	.000144	39316	5.7	24.7	65.2	10.2
2	97	FORT KNOX, KE	.000123	40670	5.0	24.7	65.2	10.2
2	98	PADUCAH, KE	.000165	34299	5.7	24.7	65.2	10.2
2	99	ALEXANDRIA, LA	.000179	45120	8.1	9.5	79.4	11.1
2	100	BOSSIER CITY, LA	.000110	45384	5.0	9.5	79.4	11.1
2	101	HOUMA, LA	.000180	33582	6.0	9.5	79.4	11.1
2	102	KENNER, LA	.000111	32514	3.6	9.5	79.4	11.1
2	103	NEW IBERIA, LA	.000196	32771	6.4	9.5	79.4	11.1
2	104	BANGOR, ME	.000076	36645	2.8	34.9	57.2	7.9
2	105	ANNAPOLIS, MD	.000247	31448	7.8	25.7	66.9	7.4
2	106	CUMBERLAND, MD	.000188	31690	6.0	25.7	66.7	7.7
2	107	HAGERSTOWN, MD	.000215	38111	8.2	25.7	66.7	7.7
2	108	ATTLEBORO, MASS	.000054	33520	1.8	29.2	63.8	6.9
2	109	GLOUCESTER, MASS	.000049	28457	1.4	29.2	63.8	6.9
2	110	MARLBOROUGH, MASS	.000058	28456	1.6	29.2	63.8	6.9
2	111	TAUNTON, MASS	.000044	44571	2.0	29.2	63.8	6.9
2	112	BATTLECREEK, MICH	.000188	40172	7.6	35.8	57.1	7.1
2	113	HOLLAND, MICH	.000111	27176	3.0	35.8	57.0	7.3
2	114	MIDLAND, MICH	.000089	36328	3.2	35.8	57.0	7.3
2	115	PORT HURON, MICH	.000256	36971	9.5	36.0	57.4	6.6
2	116	YPSILANTI, MICH	.000356	30442	10.8	36.2	57.7	6.1
2	117	AUSTIN, MN	.000182	26300	4.8	38.7	53.1	8.2
2	118	MANKATO, MN	.000173	32462	5.6	38.7	53.1	8.2
2	119	ST. CLOUD, MN	.000201	41704	8.4	39.4	54.0	6.6
2	120	WINONA, MN	.000116	27721	3.2	38.7	53.1	8.2

TABLE 29 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
2	121	COLUMBUS, MI	.000177	28087	5.0	14.1	75.4	10.4
2	122	GREENVILLE, MI	.000280	43171	12.1	14.1	75.4	10.4
2	123	HATTIESBURG, MI	.000136	41674	5.7	14.1	75.4	10.4
2	124	MERIDIAN, MI	.000116	49089	5.7	14.1	75.4	10.4
2	125	PASCAGOULA, MI	.000113	29912	3.4	14.1	75.4	10.4
2	126	VISKSBURG, MI	.000143	27859	4.0	14.1	75.4	10.4
2	127	CAPE GIRARDEAU, MO	.000088	31850	2.8	14.1	75.4	10.4
2	128	FERGUSON, MO	.000222	29706	6.6	26.3	65.1	8.7
2	129	FLORISSANT, MO	.000346	67995	23.6	26.9	66.6	6.6
2	130	FORT LEONARDWOOD, MO	.000139	34868	4.9	26.9	66.6	6.6
2	131	JEFFERSON CITY, MO	.000091	33222	3.0	26.3	65.1	8.7
2	132	JOPLIN, MO	.000076	40409	3.1	26.3	65.1	8.7
2	133	KIRKWOOD, MO	.000169	32841	5.5	26.3	65.1	8.7
2	134	RAYTOWN, MO	.000162	34649	5.6	26.9	66.6	6.6
2	135	ST. CHARLES, MO	.000162	32793	5.3	26.8	66.4	6.9
2	136	MISSOULA, MT	.000175	32651	5.7	26.4	65.4	8.2
2	137	GRAND ISLAND, NE	.000143	33103	4.7	33.5	53.7	12.8
2	138	CONCARD, NH	.000054	34252	1.8	29.5	59.8	10.7
2	139	PORTSMOUTH, NH	.000163	29878	4.9	34.8	58.1	7.1
2	140	LONG BRANCH, NJ	.000255	32576	8.3	34.8	58.1	7.1
2	141	NEW BRUNSWICK, NJ	.000309	42911	13.3	26.8	66.6	6.6
2	142	OLD BRIDGE, NJ	.000175	25811	4.5	26.8	66.6	6.6
2	143	PERTH AMBOY, NJ	.000334	39756	13.3	26.8	66.6	6.6
2	144	SAYREVILLE, NJ	.000095	33328	3.2	26.8	66.6	6.6
2	145	CLOUIS, NM	.000158	34117	5.4	26.8	66.6	6.6
2	146	HOBBS, NM	.000104	31197	3.2	22.9	65.5	11.6
2	147	LAS CRUCES, NM	.000142	45234	6.4	22.9	65.5	11.6
2	148	ROSWELL, NM	.000097	40316	3.9	22.9	65.5	11.6
2	149	SANTA FE, NM	.000099	49189	4.9	22.9	65.5	11.6
2	150	AMSTERDAM, NY	.000193	25015	4.8	22.9	65.5	11.6
2	151	AUBURN, NY	.000186	33910	6.3	31.7	62.6	5.6
2	152	ELMIRA, NY	.000247	39149	9.7	32.0	63.2	4.8
2	153	ITHACA, NY	.000203	25703	5.2	31.7	62.6	5.7
2	154	JAMESTOWN, NY	.000194	39002	7.6	32.0	63.2	4.8
2	155	KINGSTON, NY	.000149	25035	3.7	32.0	63.2	4.8
2	156	NEWBURGH, NY	.000278	25697	7.1	32.0	63.2	4.8
2	157	NIGARA FALLS, NY	.000310	83910	26.0	32.0	63.2	4.8
2	158	NORTH TONARVANDA, NY	.000169	35295	6.0	31.8	62.8	5.4
2	159	POUGHKEEPSIE, NY	.000295	32371	9.5	31.8	62.8	5.4
2	160	WATERTOWN, NY	.000154	30174	4.7	31.8	62.7	5.6

TABLE 29 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION		
						HEATING	STATIONARY	MOBILE
2	161	BURLINGTON,NC	.000166	43330	7.2	19.5	71.3	9.2
2	162	CAMP LEJUNE CENTRAL	.000150	41509	6.2	19.4	70.6	10.0
2	163	CHAPEL HILL,NC	.000212	30714	6.5	19.3	70.6	10.1
2	164	GASTTONIA,NC	.000169	56704	9.6	19.7	71.9	8.4
2	165	GOLDSBORA,NC	.000197	32254	6.3	19.4	70.6	10.0
2	166	GREENVILLE,NC	.000173	34968	6.1	19.4	70.6	10.0
2	167	KANNAPOLIS,NC	.000093	43576	4.0	19.4	70.6	10.0
2	168	ROCKY MOUNT,NC	.000190	41266	7.8	19.4	70.6	10.0
2	169	WILSON,NC	.000236	35291	8.3	19.4	70.6	10.0
2	170	BISMARCK,ND	.000197	36970	7.3	37.5	50.9	11.7
2	171	GRAND FORKS,ND	.000257	41634	10.7	37.5	50.9	11.7
2	172	MINOT,ND	.000237	34410	8.2	37.5	50.9	11.7
2	173	ALLIANCE,OH	.000204	26671	5.5	29.4	63.9	6.7
2	174	AUSTINTOWN,OH	.000177	29500	5.2	29.4	63.9	6.7
2	175	BOARDMAN,OH	.000164	31004	5.1	29.4	63.9	6.7
2	176	FAIRBORN,OH	.000213	32430	6.9	29.0	63.0	8.0
2	177	FINDLAY,OH	.000162	35968	5.8	29.4	63.9	6.7
2	178	LANCASTER,OH	.000135	33065	4.5	28.7	62.5	8.7
2	179	MARION,OH	.000268	38862	10.4	29.0	63.0	8.0
2	180	MASSILON,OH	.000186	32753	6.1	29.0	63.0	8.0
2	181	NEWARK,OH	.000169	42018	7.1	28.6	62.3	9.1
2	182	PORTSMOUTH,OH	.000119	27762	3.3	29.0	63.0	8.0
2	183	SANDUSKY,OH	.000182	32827	6.0	29.0	63.0	8.0
2	184	XENIA,OH	.000204	25492	5.2	29.0	63.0	8.0
2	185	ZANESVILLE,OH	.000204	33200	6.8	29.0	63.0	8.0
2	186	BARLESVILLE,OK	.000134	32999	4.4	18.9	62.9	18.1
2	187	ENID,OK	.000083	49544	4.1	20.2	67.3	12.5
2	188	MUSKOGEE,OK	.000073	41517	3.0	20.2	67.3	12.5
2	189	PONCA,OK	.000057	28849	1.7	20.9	69.6	9.5
2	190	SHAWNE,OK	.000035	27949	1.0	20.4	67.7	11.9
2	191	STILLWATER,OK	.000076	34616	2.6	20.2	67.3	12.5
2	192	CORVALLIS,OR	.000301	40633	12.2	25.4	65.2	9.3
2	193	MEDFORD,OR	.000166	32890	5.5	25.4	65.2	9.3
2	194	LEBANON,PA	.000286	28528	8.2	27.9	63.4	8.8
2	195	NEW CASTLE,PA	.000246	38500	9.5	27.9	63.4	8.8
2	196	STATE COLLEGE,PA	.000359	33726	12.1	27.9	63.4	8.8
2	197	WILLIAMSPORT,PA	.000205	37860	7.8	28.4	64.6	7.0
2	198	NEWPORT,RI	.000207	33941	7.0	30.1	61.8	8.2
2	199	WOONSOCKET,RI	.000262	45979	12.0	30.1	61.8	8.2
2	200	ANDERSON,SC	.000172	31023	5.3	15.8	74.9	9.3

TABLE 29 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
2	201	FLORENCE, SC	.000177	29267	5.2	15.8	74.9	9.3
2	202	ROCK HILL, SC	.000167	38104	6.4	15.8	74.9	9.3
2	203	SPARTANBURG, SC	.000192	50150	9.6	16.0	75.7	8.3
2	204	ABERDEEN, SD	.000230	27509	6.3	34.6	54.2	11.2
2	205	RAPID CITY, SD	.000148	45547	6.7	34.6	54.2	11.2
2	206	CLARKSVILLE, TN	.000077	35162	2.7	20.3	71.9	7.8
2	207	JACKSON, TN	.000141	44338	6.3	19.7	69.9	10.4
2	208	JOHNSON CITY, TN	.000128	37436	4.8	20.1	71.1	8.8
2	209	KINGSPORT, TN	.000110	35385	3.9	20.2	71.6	8.2
2	210	MURFREESBORO, TN	.000132	29221	3.9	19.9	70.6	9.4
2	211	OAK RIDGE, TN	.000026	31465	.8	19.6	69.6	10.8
2	212	BIG SPRING, TX	.000119	33624	4.0	13.2	74.8	12.0
2	213	DENTON, TX	.000083	46515	3.9	13.3	75.7	11.0
2	214	FORT HOOD, TX	.000192	38119	7.3	13.7	77.6	8.7
2	215	KILLEEN, TX	.000076	41421	3.2	13.7	77.6	8.7
2	216	KINGSVILLE, TX	.000137	33369	4.6	13.2	74.8	12.0
2	217	LONGVIEW, TX	.000115	53171	6.1	13.2	74.8	12.0
2	218	MEXQUITE, TX	.000121	61404	7.8	13.5	76.4	10.2
2	219	RICHARDSON, TX	.000100	56767	5.7	13.3	75.6	11.1
2	220	TEMPLE, TX	.000081	38999	3.2	13.7	77.6	8.7
2	221	VICTORIA, TX	.000136	48236	6.6	13.2	74.8	12.0
2	222	BURLINGTON, VT	.000260	42548	11.1	36.2	56.4	7.5
2	223	CHARLOTTESVILLE, VA	.000200	43497	8.7	21.3	70.6	8.1
2	224	DANVILLE, VA	.000158	51900	8.2	21.3	70.4	8.3
2	225	BELLINGHAM, WA	.000127	42613	5.4	29.4	60.0	10.6
2	226	BREMERTON, WA	.000220	38206	8.4	29.4	60.0	10.6
2	227	FORT LEWIS, WA	.000172	41178	7.1	30.1	61.5	8.5
2	228	LAKES DISTRICT, WA	.000193	52103	10.1	30.1	61.5	8.5
2	229	LONGVIEW, WA	.000159	30703	4.9	29.4	60.0	10.6
2	230	RICHLAND, WA	.000073	28441	2.1	30.3	61.9	7.8
2	231	YAKIMA, WA	.000250	49332	12.3	29.3	59.8	10.9
2	232	FAIRMONT, WV	.000224	27865	6.2	24.7	66.1	9.2
2	233	MORGANTOWN, WV	.000320	31594	10.1	24.7	66.1	9.2
2	234	PARKERSBURG, WV	.000310	47517	14.7	25.0	67.0	8.0
2	235	BELOIT, WI	.000135	37880	5.1	35.4	58.5	6.1
2	236	EAU CLAIRE, WI	.000115	47288	5.4	35.4	58.5	6.1
2	237	FONDDULAC, WI	.000177	37847	6.7	35.4	58.5	6.1
2	238	JAMESVILLE, WI	.000125	49221	6.1	35.4	58.5	6.1
2	239	MANITOWOC, WI	.000145	35513	5.2	35.4	58.5	6.1
2	240	SHEBOYGAN, WI	.000237	51446	12.2	35.4	58.5	6.1

TABLE 29 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
2	241	WAUSAU, WI	.000133	34781	4.6	35.4	58.5	6.1
2	242	CASPER, WY	.000248	49595	12.3	32.4	54.8	12.9
2	243	CHEYENNE, WY	.000192	51324	9.9	32.4	54.8	12.9

Source: Systems Applications, Incorporated computations.

TABLE 30. BERYLLIUM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS IN TYPE III CITIES

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION		
						HEATING	STATIONARY	MOBILE
3	1	ARAB,AL	.000033	4756	.2	10.2	74.4	15.4
3	2	BAY MINETTE,AL	.000041	7273	.3	10.5	76.8	12.6
3	3	IRONDALE,AL	.000040	3423	.1	10.9	79.7	9.4
3	4	CONWAY,AR	.000106	17550	1.9	19.1	70.1	10.8
3	5	ENGLAND,AR	.000088	3479	.3	19.1	70.1	10.8
3	6	LAKE VILLAGE,AR	.000083	3745	.3	19.1	70.1	10.8
3	7	MENA,AR	.000049	5125	.3	19.1	70.1	10.8
3	8	MONTICELLO,AR	.000086	5754	.5	19.1	70.1	10.8
3	9	RUSSELLVILLE,AR	.000098	13295	1.3	19.1	70.1	10.8
3	10	WALNUT RIDGE,AR	.000084	4299	.4	19.1	70.1	10.8
3	11	ALTURAS,CA	.000051	3107	.2	15.6	74.7	9.7
3	12	BANNING,CA	.000046	13360	.6	15.7	75.0	9.4
3	13	CARMEL VALLEY,CA	.000020	3359	.1	15.7	75.2	9.1
3	14	CHINA LAKE,CA	.000075	12329	.9	15.5	73.9	10.7
3	15	CUCAMONGA,CA	.000078	6435	.5	15.3	73.0	11.7
3	16	EUREKA,CA	.000090	27020	2.4	15.6	74.7	9.7
3	17	GRIDLEY,CA	.000139	3923	.5	15.6	74.7	9.7
3	18	LAMONT,CA	.000184	7779	1.4	15.5	73.9	10.7
3	19	NEWHALL,CA	.000111	10715	1.2	15.9	75.8	8.3
3	20	PALMDALE,CA	.000011	9449	.1	15.9	75.8	8.3
3	21	SANTA MARIA,CA	.000129	7915	1.0	15.8	75.4	8.8
3	22	SUISAN CITY,CA	.000090	3238	.3	15.8	75.8	8.4
3	23	BRIGHTON,CO	.000176	10067	1.8	29.7	60.5	9.8
3	24	GOLDEN,CO	.000111	11894	1.3	29.7	60.7	9.6
3	25	DANIELSON,CN	.000182	4711	.9	31.8	61.5	6.7
3	26	ORANGETOWN,CN	.000048	13912	.7	31.8	61.5	6.7
3	27	SIMSBURY CENTER,CN	.000058	5137	.3	31.8	61.5	6.7
3	28	WILLIMANTIC,CN	.000167	14815	2.5	31.8	61.5	6.7
3	29	MEMPHIS,FL	.000088	4103	.4	5.3	84.9	9.8
3	30	MIAMI SHORES,FL	.000172	12059	2.1	5.3	84.9	9.8
3	31	PERRY,FL	.000041	9853	.4	5.3	84.9	9.8
3	32	CARROLLTON,GA	.000067	15069	1.0	18.2	72.1	9.7
3	33	LARKSTON,GA	.000186	3485	.6	18.6	73.9	7.5
3	34	SMYRNATOWN,GA	.000108	21352	2.3	18.0	71.6	10.3
3	35	HALEUVA,HAW	.000040	3114	.1	0.	91.5	8.5
3	36	CHUBBUCK,ID	.000032	3600	.1	28.4	59.9	11.7
3	37	ALSID,IL	.000065	11292	.7	32.3	62.9	4.8
3	38	CENTREVILLE,IL	.000122	11532	1.4	31.3	61.1	7.5
3	39	CHESTER,IL	.000036	5302	.2	31.3	61.1	7.5
3	40	CLARENDON HILLS,IL	.000173	6841	1.2	31.6	61.7	6.7

TABLE 30 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
3	41	EFFINGHAM, IL	.000126	9586	1.2	31.3	61.1	7.5
3	42	HENRY, IL	.000097	2645	.3	31.3	61.1	7.5
3	43	LA GRANGE PARK, IL	.000268	15669	4.2	32.3	62.9	4.8
3	44	LAWRENCEVILLE, IL	.000118	5942	.7	31.3	61.1	7.5
3	45	LYONS, IL	.000228	11275	2.6	32.3	62.9	4.8
3	46	SPARTA, IL	.000112	4365	.5	31.3	61.1	7.5
3	47	AURORA, IN	.000073	4420	.3	29.1	64.0	6.9
3	48	AUSTIN, IN	.000098	5047	.5	29.1	64.0	6.9
3	49	HOBART, IN	.000076	22122	1.7	29.4	64.7	5.9
3	50	DENISON, IA	.000031	6354	.3	31.8	58.1	10.1
3	51	ELDORA, IA	.000032	3293	.1	31.8	58.1	10.1
3	52	MOUNT VERNON, IA	.000094	3084	.3	31.8	58.1	10.1
3	53	ONAWA, IA	.000031	3223	.1	31.8	58.1	10.1
3	54	WINTERSET, IA	.000093	3734	.3	31.8	58.1	10.1
3	55	CONCORDIA, KA	.000085	7503	.6	24.3	63.6	12.1
3	56	MULVANE, KA	.000093	3309	.3	25.0	65.4	9.6
3	57	PHILLPSBURG, KA	.000083	3367	.3	24.3	63.6	12.1
3	58	DAWSON SPRING, KN	.000044	3263	.1	24.7	65.2	10.2
3	59	FORT WRIGHT-LOOKOUT	.000115	5226	.6	24.7	65.2	10.2
3	60	JENKINS, KN	.000023	2767	.1	24.7	65.2	10.2
3	61	OKOLONA, KN	.000140	19133	2.7	25.4	67.1	7.5
3	62	CARIBOU, ME	.000083	11511	1.0	34.9	57.2	7.9
3	63	FARMINGTON CENTER	.000061	3420	.2	34.9	57.2	7.9
3	64	KITTERY CENTER, ME	.000173	8134	1.4	34.9	57.2	7.9
3	65	BAINBRIDGE, MD	.000117	5586	.7	25.7	66.7	7.7
3	66	PALMER PARK, MD	.000386	8684	3.4	25.7	66.8	7.5
3	67	DUXBURYTOWN, MASS	.000014	7778	.1	29.2	63.8	6.9
3	68	GREENFIELDTOWN, MASS	.000036	18453	.7	29.2	63.8	6.9
3	69	HADLEYTOWN, MASS	.000007	3819	.0	29.2	63.8	6.9
3	70	ORANGE CENTER, MASS	.000050	3918	.2	29.2	63.8	6.9
3	71	TEMPLETONTOWN, MASS	.000008	5972	.0	29.2	63.8	6.9
3	72	WARETOWN, MASS	.000011	8339	.1	29.2	63.8	6.9
3	73	WILMINGTONTOWN, MASS	.000041	17420	.7	29.2	63.8	6.9
3	74	FREMONT, MICH	.000063	3575	.2	35.8	57.0	7.3
3	75	GAYLORD, MICH	.000066	3108	.2	35.8	57.0	7.3
3	76	GROSSE ILE, MICH	.000056	8570	.5	36.5	58.1	5.5
3	77	LEVEL PARK-OAK PARK	.000074	3178	.2	35.8	57.1	7.1
3	78	ST. LOUIS, MICH	.000103	4231	.4	35.8	57.0	7.3
3	79	LAKE CITY, MN	.000054	4154	.2	39.0	53.5	7.5
3	80	MINNETRISTA, MN	.000007	3023	.0	39.7	54.4	5.9

TABLE 30 (Continued)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
3	81	MORA,MN	.000036	2712	.1	38.7	53.1	8.2
3	82	MACON,MISS	.000038	2844	.1	14.1	75.4	10.4
3	83	MORTON,MISS	.000047	2909	.1	14.1	75.4	10.4
3	84	AVA,MISS	.000046	2579	.1	26.3	65.1	8.7
3	85	BUTLER,MISS	.000071	4104	.3	26.3	65.1	8.7
3	86	DEXTER,MISS	.000074	6203	.5	26.3	65.1	8.7
3	87	CENTRAL CITY,NE	.000067	2967	.2	29.1	59.0	11.9
3	88	EXETERTOWN,NH	.000044	10145	.4	34.8	58.1	7.1
3	89	HAMPTONTOWN,NH	.000055	9139	.5	35.2	58.8	6.0
3	90	HILLSBOROGHTOWN,NH	.000007	3166	.0	35.2	58.8	6.0
3	91	HINSDALETOWN,NH	.000016	3737	.1	34.8	58.1	7.1
3	92	NEWMARKET COMPACT,N	.000093	3017	.3	34.8	58.1	7.1
3	93	WOLFEBOROTOWN,NH	.000007	3463	.0	34.8	58.1	7.1
3	94	DUMONT,NJ	.000402	20663	8.3	26.8	66.6	6.6
3	95	KENDALL PARK,NJ	.000100	7599	.8	26.8	66.6	6.6
3	96	LITTLE SILVER,NJ	.000081	6161	.5	26.8	66.6	6.6
3	97	MOORESTOWN-LENOLA	.000085	14527	1.2	26.8	66.6	6.6
3	98	NEW MILFORD,NJ	.000308	19632	6.1	26.8	66.6	6.6
3	99	NORTH CAPE MAY,NJ	.000174	3908	.7	26.8	66.6	6.6
3	100	ELMA CENTER,NY	.000022	2728	.1	32.0	63.2	4.8
3	101	LAKE CARMEL,NY	.000105	4700	.5	32.0	63.2	4.8
3	102	LITTLE FALLS,NY	.000078	7477	.6	31.8	62.8	5.4
3	103	NEWMARK,NY	.000102	11412	1.2	31.3	61.7	7.0
3	104	NEW YORK MILLS,NY	.000147	3729	.5	31.8	62.8	5.3
3	105	NORTH BELLPORT,NY	.000073	5785	.4	31.7	62.6	5.7
3	106	NORTH MASSAPEQUA,NY	.000331	22662	7.5	31.8	62.7	5.6
3	107	RYE,NY	.000123	15553	1.9	31.8	62.9	5.3
3	108	SCOTIA,NY	.000153	7223	1.1	31.7	62.6	5.6
3	109	TICONDEROGA,NY	.000085	3202	.3	32.0	63.2	4.8
3	110	VOORHEESVILLE,NY	.000050	2769	.1	31.9	62.9	5.2
3	111	KERNSVILLE,NC	.000092	5790	.5	19.5	71.1	9.4
3	112	NEW RIVER-GIEGER,NC	.000077	10461	.8	19.4	70.6	10.0
3	113	STANFORD,NC	.000161	14089	2.3	19.4	70.6	10.0
3	114	BRUNSWICK,OH	.000077	15926	1.2	28.9	62.9	8.2
3	115	GREENSVILLE,OH	.000187	6120	1.1	29.0	63.0	8.0
3	116	NEW PHILADELPHIA,OH	.000160	15255	2.4	29.0	63.0	8.0
3	117	ADA,OK	.000086	16525	1.4	20.2	67.3	12.5
3	118	LINDSAY,OK	.000087	4120	.4	20.2	67.3	12.5
3	119	SULPHUR,OK	.000054	5736	.3	20.2	67.3	12.5
3	120	BLAKELY,PA	.000071	6381	.5	28.4	64.6	7.1

TABLE 30 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	EXPO LEVEL (UG/(M)3)	POP (PERSON)	DOSAGE (UG/(M)3 -PERSON)	PERCENTAGE OF CONTRIBUTION HEATING	STATIONARY	MOBILE
3	121	DOYLESTOWN,PA	.000118	8257	1.0	28.5	64.8	6.8
3	122	GETTYSBURG,PA	.000148	7263	1.1	28.4	64.7	6.8
3	123	LIBERTY,PA	.000094	3508	.3	28.3	64.5	7.2
3	124	ST. CLARI,PA	.000139	4569	.6	27.8	63.1	9.1
3	125	SLIPPERY,ROCK,PA	.000118	4941	.6	27.9	63.4	8.8
3	126	TYRONE,PA	.000175	7061	1.2	28.4	64.6	7.0
3	127	VANDERGRIFT,PA	.000234	7876	1.8	28.4	64.6	7.0
3	128	WEST WARWICKTOWN,RI	.000130	23886	3.1	30.1	61.8	8.2
3	129	CAPEHART,SC	.000134	5054	.7	15.8	74.9	9.3
3	130	CONWAY,SC	.000096	9176	.9	15.8	74.9	9.3
3	131	MOBRIDGE,SD	.000125	4722	.6	34.6	54.2	11.2
3	132	LA FOLLETTE,TN	.000161	7651	1.2	19.7	69.9	10.4
3	133	ROCKWOOD,TN	.000075	5829	.4	19.7	69.9	10.4
3	134	BURNET,TX	.000036	3341	.1	13.2	74.8	12.0
3	135	CROWLEY,TX	.000020	3105	.1	13.4	75.9	10.7
3	136	FROMIA,TX	.000095	3629	.3	13.2	74.9	12.0
3	137	LOCKHART,TX	.000070	7569	.5	13.2	74.8	12.0
3	138	LULING,TX	.000084	5505	.5	13.2	74.8	12.0
3	139	PORTLAND,TX	.000085	8518	.7	13.5	76.8	9.6
3	140	SAN AUGUSTINE,TX	.000025	2961	.1	13.2	74.8	12.0
3	141	SEALY,TX	.000062	3132	.2	13.2	74.8	12.0
3	142	SILSKEE,TX	.000068	8482	.6	13.3	75.2	11.6
3	143	PRICE,UT	.000188	7621	1.4	29.8	61.1	9.2
3	144	RADFORD,VI	.000113	12973	1.5	21.3	70.6	8.1
3	145	LYDEN,WA	.000096	3038	.3	29.4	60.0	10.6
3	146	STEILACOOM,WA	.000080	3084	.2	30.1	61.5	8.5
3	147	HARTLAND,WI	.000043	2929	.1	35.5	58.6	5.9
3	148	MEDFORD,WI	.000061	3661	.2	35.4	58.5	6.1
3	149	SOUTH MILWAUKEE,WI	.000208	24699	5.1	36.1	59.6	4.3
3	150	GREEN RIVER,WY	.000046	5270	.2	32.4	54.8	12.9

Source: Systems Applications, Incorporated computations.

TABLE 31. SUMMARY OF BERYLLIUM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.002500	565140	1758.9	13.8	82.4	3.8	100.0	0.	0.
.001000	9149730	16754.3	30.8	66.6	2.6	100.0	0.	0.
.000500	28601329	30552.2	28.9	66.7	4.4	100.0	0.	0.
.000250	73351092	45256.6	27.7	67.2	5.1	97.8	.8	1.3
.000100	139664758	56842.5	26.9	67.4	5.8	94.2	2.5	3.3
0.	158679135	58136.8	26.8	67.4	5.8	92.8	2.6	4.6

TABLE 32. EXPOSURE/DOSAGE ANALYSIS DATA BASE FOR TYPE I CITY AREA SOURCES

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	1	ABILENE,TX	INNER CITY	74.9	89486	46430	15722
			URBAN FRINGE	3.1	1085	563	191
1	2	AKRON,OH	INNER CITY	54.2	275420	152808	18612
			URBAN FRINGE	149.8	267365	148323	18066
1	3	ALBANY,GA	INNER CITY	29.4	72623	34362	7490
			URBAN FRINGE	3.6	3889	1840	401
1	4	ALBANY,NY	INNER CITY	41.3	256657	110021	15177
			URBAN FRINGE	109.7	229868	98538	13593
1	5	ALBUQUERQUE,NM	INNER CITY	82.8	243751	125567	36807
			URBAN FRINGE	31.8	53700	27663	8109
1	6	ALLENTOWN,PA	INNER CITY	41.8	212461	100710	15304
			URBAN FRINGE	57.2	151110	71629	10942
1	7	ALTOONA,PA	INNER CITY	9.1	62898	30066	4592
			URBAN FRINGE	10.9	18897	9031	1308
1	8	AMARILLO,TX	INNER CITY	61.0	122010	74794	20640
1	9	ANDERSON,IN	INNER CITY	37.1	70853	33153	7318
			URBAN FRINGE	5.9	9051	4609	1017
1	10	ANN ARBOR,MI	INNER CITY	21.8	99797	47793	7201
			URBAN FRINGE	23.2	70808	37741	5687
1	11	APPLETON,WI	INNER CITY	12.7	57406	25054	4183
			URBAN FRINGE	24.3	72486	31836	6315
1	12	ASHEVILLE,NC	INNER CITY	22.3	57571	28933	7705
			URBAN FRINGE	15.7	14800	7478	1992
1	13	ATLANTA,GA	INNER CITY	131.5	497024	292325	53721
			URBAN FRINGE	303.5	675754	397445	73038
1	14	ATLANTIC CITY,NJ	INNER CITY	12.4	47889	24998	2782
			URBAN FRINGE	54.6	86127	44958	5004
1	15	AUGUSTA,GA	INNER CITY	15.2	59864	30977	5826
			URBAN FRINGE	42.7	89009	46100	8671
1	16	AURORA,IL	INNER CITY	28.7	129988	63824	13389
			URBAN FRINGE	48.3	102929	50538	10602
1	17	AUSTIN,TX	INNER CITY	72.1	251817	127158	20884
			URBAN FRINGE	13.9	12682	6404	1453
1	18	BAKERSFIELD,CA	INNER CITY	25.9	69515	34446	12817
			URBAN FRINGE	31.1	107640	53337	19846
1	19	BALTIMORE,MD	INNER CITY	78.3	905759	401240	57892
			URBAN FRINGE	231.7	674022	298580	43080
1	20	BATON ROUGE,LA	INNER CITY	40.4	165970	73027	20215
			URBAN FRINGE	44.6	83493	36737	14194
1	21	BAY CITY,MI	INNER CITY	10.0	49449	23307	4566
			URBAN FRINGE	16.0	28640	13503	2646

TABLE 32 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	43	CHATTANOGA,TENN	INNER CITY	52.5	119876	62483	13517
			URBAN FRINGE	64.5	103683	54008	11689
1	44	CHICAGO,IL	INNER CITY	301.0	3692790	1595941	143498
			URBAN FRINGE	976.0	3021700	1305949	117424
1	45	CINCINNATI,OH	INNER CITY	78.1	452550	231191	26254
			URBAN FRINGE	256.9	657964	336130	30171
1	46	CLEVELAND,OH	INNER CITY	75.9	751046	393203	30272
			URBAN FRINGE	570.1	1200834	636225	40724
1	47	COLORADO SPRINGS,CO	INNER CITY	60.8	135017	75402	10172
			URBAN FRINGE	29.2	69749	38952	9300
1	48	COLUMBIA,MO	INNER CITY	42.0	58577	23228	6628
1	49	COLUMBIA,SC	INNER CITY	103.0	241781	128309	25141
1	50	COLUMBUS,GA	INNER CITY	69.5	154098	76198	12532
			URBAN FRINGE	36.5	54518	26958	4434
1	51	COLUMBUS,OH	INNER CITY	135.0	539377	28955	31764
			URBAN FRINGE	100.0	250642	134552	14760
1	52	CORPUS CHRISTI,TX	INNER CITY	101.0	204599	97249	26486
			URBAN FRINGE	29.0	8230	3912	1065
1	53	DALLAS,TX	INNER CITY	266.0	844189	401794	113305
			URBAN FRINGE	400.0	494495	276960	66370
1	54	DANBURY,CONN	INNER CITY	44.0	50781	31281	2723
			URBAN FRINGE	11.0	15870	9776	851
1	55	DAVENPORT,IOWA	INNER CITY	84.0	195041	103278	19448
			URBAN FRINGE	34.0	70078	37108	6988
1	56	DAYTON,OH	INNER CITY	30.3	243459	137573	16201
			URBAN FRINGE	105.7	442483	250037	29445
1	57	DECATUR,IL	INNER CITY	30.6	90705	47720	11197
			URBAN FRINGE	6.4	8988	4729	1110
1	58	DENVER,CO	INNER CITY	95.2	514678	307477	70739
			URBAN FRINGE	201.8	532633	318203	73207
1	59	DES MOINES,IOWA	INNER CITY	63.2	200772	107236	22047
			URBAN FRINGE	45.8	55052	29404	6045
1	60	DETROIT,MI	INNER CITY	130.0	1511336	745236	86724
			URBAN FRINGE	734.0	2459248	1212682	141118
1	61	DUBUQUE,IOWA	INNER CITY	16.4	62313	27073	5966
			URBAN FRINGE	2.6	3237	1409	310
1	62	DULUTH MN	INNER CITY	105.0	132790	58774	15002
			URBAN FRINGE	6.0	5562	2462	662
1	63	DURHAM,NC	INNER CITY	36.6	95412	54903	13266
			URBAN FRINGE	6.4	5352	3000	744

TABLE 32 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	22	BEAUMONT, TX	INNER CITY	71.6	115968	57382	16164
			URBAN FRINGE	3.4	305	190	40
1	23	BILLINGS, MONT	INNER CITY	14.7	61581	32949	12414
			URBAN FRINGE	12.3	9616	5145	1939
1	24	BILOXI, MS	INNER CITY	37.0	89236	38853	9814
			URBAN FRINGE	27.0	32635	14092	3560
1	25	BINGHAMTON, NY	INNER CITY	11.0	64123	27873	4156
			URBAN FRINGE	41.0	103101	44816	6683
1	26	BIRMINGHAM, AL	INNER CITY	79.5	300687	162547	34785
			URBAN FRINGE	145.5	257412	139151	29779
1	27	BLOOMINGTON, IL	INNER CITY	15.6	66032	31258	7172
			URBAN FRINGE	4.4	3090	1435	334
1	28	BOISE CITY, ID	INNER CITY	23.4	74990	42983	8336
			URBAN FRINGE	5.6	10187	5039	1132
1	29	BOSTON, MASS	INNER CITY	46.0	641053	316039	36989
			URBAN FRINGE	618.0	2011522	991680	116065
1	30	BOULDER, CO	INNER CITY	13.0	66870	39949	9191
			URBAN FRINGE	1.0	1764	1054	242
1	31	BRIDGEPORT, CONN	INNER CITY	16.1	156546	96432	8391
			URBAN FRINGE	132.9	256820	158201	13766.
1	32	BRISTOL, CONN	INNER CITY	26.6	55487	34180	2974
			URBAN FRINGE	10.4	16245	10007	871
1	33	BROCKTON, MASS	INNER CITY	21.2	89040	43897	5138
			URBAN FRINGE	31.8	59804	29483	3451
1	34	BROWNSVILLE, TX	INNER CITY	15.0	55627	21006	5833
1	35	BRYAN, TX	INNER CITY	16.8	33719	14892	4328
			URBAN FRINGE	16.2	17676	7006	2269
1	36	BUFFALO, NY	INNER CITY	41.3	462783	190212	19944
			URBAN FRINGE	172.7	623811	256397	26884
1	37	CANTON, OH	INNER CITY	19.0	109939	59330	8172
			URBAN FRINGE	58.0	134340	72098	9983
1	38	CEDAR RAPIDS, IOWA	INNER CITY	50.7	110642	56838	11445
			URBAN FRINGE	11.3	21366	10976	2210
1	39	CHAMPAIGN-URBANA, IL	INNER CITY	13.4	89377	40114	7657
			URBAN FRINGE	4.6	11040	4955	946
1	40	CHARLESTON, SC	INNER CITY	17.2	66934	30334	5560
			URBAN FRINGE	81.8	161465	73174	13412
1	41	CHARLESTON, WV	INNER CITY	27.2	71505	30359	8001
			URBAN FRINGE	34.8	86157	36579	9640
1	42	CHARLOTTE, NC	INNER CITY	76.0	241215	137723	20478
			URBAN FRINGE	30.0	38315	21876	4524

TABLE 32 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	64	EL PASO, TX	INNER CITY	119.0	337471	182847	32407
1	65	ERIE, PA	INNER CITY	18.9	129220	61077	9503
			URBAN FRINGE	25.1	46043	21746	3306
1	66	EUGENE, OR	INNER CITY	26.1	76341	45744	7430
			URBAN FRINGE	20.9	62914	37698	6123
1	67	EVANSVILLE, IN	INNER CITY	36.0	138690	65281	18915
			URBAN FRINGE	5.0	3786	1782	516
1	68	FALL RIVER, MASS	INNER CITY	33.0	96931	53603	7638
			URBAN FRINGE	10.0	42461	23481	3346
1	69	FARGO, ND	INNER CITY	18.0	83029	40270	13129
			URBAN FRINGE	8.0	2417	1172	382
1	70	FAYETTEVILLE, NC	INNER CITY	23.4	53510	23714	4069
			URBAN FRINGE	49.6	107860	47800	8203
1	71	FITCHBURG, MASS	INNER CITY	56.3	76282	37607	4401
			URBAN FRINGE	4.7	1771	873	102
1	72	FLINT, MI	INNER CITY	32.8	193308	93678	17633
			URBAN FRINGE	63.2	136748	66244	12469
1	73	FORT LAUDERDALE, FL	INNER CITY	55.0	246555	171970	21076
			URBAN FRINGE	157.0	367242	286148	31392
1	74	FORT SMITH, AR	INNER CITY	45.0	62802	28558	13782
			URBAN FRINGE	15.0	12715	5782	2790
1	75	FORT WAYNE, IN	INNER CITY	51.5	177738	83953	18295
			URBAN FRINGE	17.5	47446	22411	4884
1	76	FORT WORTH, TX	INNER CITY	205.0	393463	219896	52810
			URBAN FRINGE	191.0	283481	158430	30048
1	77	FRESNO, CA	INNER CITY	41.8	165972	82731	28396
			URBAN FRINGE	37.2	96936	48319	16584
1	78	GADSDEN, AL	INNER CITY	32.4	53911	31933	7424
			URBAN FRINGE	22.6	13795	8171	1900
1	79	GAINSVILLE, FL	INNER CITY	26.1	64510	36566	7478
			URBAN FRINGE	2.9	4819	2732	559
1	80	GALVESTON, TX	INNER CITY	23.0	61809	28575	7178
1	81	GRAND RAPIDS, MI	INNER CITY	44.9	197534	101048	17873
			URBAN FRINGE	101.1	155169	79377	14040
1	82	GREAT FALLS, MT	INNER CITY	14.7	60091	29336	10705
			URBAN FRINGE	7.3	10814	5328	1926
1	83	GREEN BAY, WI	INNER CITY	41.7	87684	38903	6635
			URBAN FRINGE	36.3	41421	18378	3134
1	84	GREENSBORO, NC	INNER CITY	54.4	144245	83323	16416
			URBAN FRINGE	6.6	8007	4625	911

TABLE 32 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	85	GREENSVILLE,SC	INNER CITY	20.7	61200	32624	6607
			URBAN FRINGE	50.3	96065	51630	10456
1	86	HAMILTON,OH	INNER CITY	16.0	67617	35751	5009
			URBAN FRINGE	22.0	23295	12317	1726
1	87	HARLINGEN,TX	INNER CITY	22.5	33515	12728	3512
			URBAN FRINGE	11.5	16954	6439	1701
1	88	HARRISBURY,PA	INNER CITY	7.6	67000	32002	4000
			URBAN FRINGE	70.4	172071	81499	12449
1	89	HARTFORD,CONN	INNER CITY	17.4	158017	97338	8470
			URBAN FRINGE	113.6	306907	109104	16435
1	90	HIGH POINT,NC	INNER CITY	30.8	63105	36453	7182
			URBAN FRINGE	21.2	30442	17585	3464
1	91	HONOLULU,HAWAII	INNER CITY	83.9	324071	160760	17600
			URBAN FRINGE	31.1	117524	58159	6396
1	92	HOUSTON,TX	INNER CITY	434.0	1232407	646833	161293
			URBAN FRINGE	105.0	445456	233799	58300
1	93	HUNTINGTON,WV	INNER CITY	22.7	103567	47136	11320
			URBAN FRINGE	33.3	64016	29136	6997
1	94	HUNSVILLE,AL	INNER CITY	109.1	137078	83438	21552
			URBAN FRINGE	13.9	8687	5257	1358
1	95	INDIANAPOLIS,IN	INNER CITY	381.0	820259	364704	72469
1	96	JACKSON,MI	INNER CITY	10.7	45481	21970	4553
			URBAN FRINGE	25.3	33091	15985	3313
1	97	JACKSON,MS	INNER CITY	50.2	153968	75600	19696
			URBAN FRINGE	21.8	46092	22632	5896
1	98	JACKSONVILLE,FL	INNER CITY	351.0	529585	295340	57369
1	99	JOHNSTOWN,PA	INNER CITY	5.7	42476	20168	3038
			URBAN FRINGE	22.3	53670	25483	3892
1	100	JOLIET,IL	INNER CITY	16.5	78644	30614	8100
			URBAN FRINGE	38.5	76856	37736	7916
1	101	KALAMAZOO,MI	INNER CITY	24.5	85661	41104	8605
			URBAN FRINGE	48.5	66422	31872	6672
1	102	KANSASCITY,MO	INNER CITY	373.0	675391	337022	65380
			URBAN FRINGE	120.0	426396	213270	41282
1	103	KENOSHA,WI	INNER CITY	13.7	78817	37654	5358
			URBAN FRINGE	4.3	5445	2601	370
1	104	KNOXVILLE,TENN	INNER CITY	77.0	174587	89902	16401
			URBAN FRINGE	9.0	15915	8195	1495
1	105	LA CROSSE,WI	INNER CITY	15.2	51153	22366	4357
			URBAN FRINGE	8.8	12220	5343	1041

TABLE 32 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	106	LAFAYETTE, LA	INNER CITY	20.0	68984	30383	11727
			URBAN FRINGE	5.0	9560	4206	1625
1	107	LAFAYETTE, IN	INNER CITY	8.7	44955	18329	4155
			URBAN FRINGE	10.3	34162	13928	3157
1	108	LAKE CHARLES, LA	INNER CITY	23.0	77998	34319	13264
			URBAN FRINGE	11.0	10262	4515	1745
1	109	LANCASTER, PA	INNER CITY	7.2	57589	27051	4132
			URBAN FRINGE	31.8	59508	27953	4270
1	110	LANSING, MI	INNER CITY	33.4	131638	61761	12479
			URBAN FRINGE	39.6	97880	45923	9279
1	111	LAREDO, TX	INNER CITY	20.5	68937	24973	3175
			URBAN FRINGE	1.5	1260	456	58
1	112	LAS VEGAS, NV	INNER CITY	51.6	125641	77418	18779
			URBAN FRINGE	69.4	111040	68421	16596
1	113	LAWRENCE, MASS	INNER CITY	39.1	113047	85732	6523
			URBAN FRINGE	44.9	87233	43006	5033
1	114	LAWTON, OK	INNER CITY	31.2	74627	42118	12331
			URBAN FRINGE	12.8	21060	11886	3542
1	115	LEWISTON, MAINE	INNER CITY	34.6	41779	21266	6016
			URBAN FRINGE	33.4	23433	11927	3374
1	116	LEXINGTON, KY	INNER CITY	23.0	108137	56230	13639
			URBAN FRINGE	17.0	51401	26728	6492
1	117	LIMA, OH	INNER CITY	11.7	53482	29939	8309
			URBAN FRINGE	15.3	16813	9412	1669
1	118	LINCOLN, NEB	INNER CITY	49.3	149518	71662	14482
			URBAN FRINGE	2.7	3925	1881	380
1	119	LITTLE ROCK, AR	INNER CITY	49.3	149518	72982	21207
			URBAN FRINGE	45.7	73098	35680	10368
1	120	LORAIN, OH	INNER CITY	40.0	132148	74633	8463
			URBAN FRINGE	66.0	60117	33952	3050
1	121	LOS ANGELES, CA	INNER CITY	590.0	3619982	1946951	313020
			URBAN FRINGE	982.0	4731284	2544647	409117
1	122	LOUISVILLE, KY	INNER CITY	60.0	361453	183982	32064
			URBAN FRINGE	150.0	377943	192376	33527
1	123	LOWELL, MASS	INNER CITY	13.6	94251	46466	8438
			URBAN FRINGE	48.4	98400	48551	5682
1	124	LUBBOCK, TX	INNER CITY	77.0	150135	75574	21438
1	125	LYNCHBURG, VA	INNER CITY	25.1	54083	24822	6244
			URBAN FRINGE	11.9	16759	7691	1935
1	126	MACON, GA	INNER CITY	49.0	122423	64267	12802
			URBAN FRINGE	2.0	5642	2962	590

TABLE 32 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	127	MADISON,WI	INNER CITY	48.6	173242	79782	12384
			URBAN FRINGE	20.5	32215	14836	2303
1	128	MANCHESTER,NH	INNER CITY	32.1	87754	47387	8863
			URBAN FRINGE	6.9	7306	3908	746
1	129	MANSFIELD,OH	INNER CITY	24.1	55001	33563	4968
			URBAN FRINGE	16.9	22598	13790	2041
1	130	MCALLEN,TX	INNER CITY	13.5	37636	13435	4715
			URBAN FRINGE	19.5	53505	19100	6703
1	131	MEMPHIS,MS	INNER CITY	196.0	663976	295718	69658
1	132	MERIDEN,CONN	INNER CITY	23.7	55959	34471	2999
			URBAN FRINGE	47.3	42495	26177	2278
1	133	MIAMI,FL	INNER CITY	34.3	335075	210362	21150
			URBAN FRINGE	224.7	884595	553353	35055
1	134	MIDLAND,TX	INNER CITY	29.2	59609	37054	9118
			URBAN FRINGE	2.8	602	423	104
1	135	MILWAUKEE,WI	INNER CITY	95.0	717124	323739	32492
			URBAN FRINGE	362.0	535333	241686	24255
1	136	MINNEAPOLIS,MN	INNER CITY	107.0	744321	369808	60958
			URBAN FRINGE	614.0	960102	477010	70630
1	137	MOBILE,AL	INNER CITY	116.6	189906	94947	22252
			URBAN FRINGE	51.4	67830	33098	7944
1	138	MODESTO,CA	INNER CITY	9.5	61712	32010	12132
			URBAN FRINGE	24.5	44395	23028	8727
1	139	MONROE,LA	INNER CITY	22.2	56374	24805	9584
			URBAN FRINGE	17.8	34193	15045	5813
1	140	MONTGOMERY,AL	INNER CITY	4.6	413347	107069	1516
			URBAN FRINGE	4.6	5512	2919	626
1	141	MUNCIE,IN	INNER CITY	12.8	69132	29635	7454
			URBAN FRINGE	12.2	21295	9129	2296
1	142	MUSKEGON,MI	INNER CITY	13.0	44631	20517	4105
			URBAN FRINGE	39.0	61005	20081	5618
1	143	NASHUA,NH	INNER CITY	31.4	55200	30143	5638
			URBAN FRINGE	2.6	5141	2776	519
1	144	NASHVILLE,TENN	INNER CITY	344.0	440444	220683	49134
1	145	NEW BEDFORD,MASS	INNER CITY	19.5	101759	50167	3071
			URBAN FRINGE	14.5	31908	15731	1841
1	146	NEW BRITAIN,CONN	INNER CITY	13.3	83441	51400	4472
			URBAN FRINGE	23.7	47908	29511	2568
1	147	NEW HAVEN,CONN	INNER CITY	18.4	137715	84832	7302
			URBAN FRINGE	88.6	210626	129746	11290

TABLE 32 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
I	148	NEW ORLEANS, LA	INNER CITY	184.0	961728	423160	163494
I	149	NEW YORK, NY	INNER CITY	362.0	8020151	2017343	113014
			URBAN FRINGE	2063.0	7386690	1689400	95317
I	150	NEWPORT, VA	INNER CITY	123.8	258956	120402	17525
			URBAN FRINGE	19.2	9307	4327	630
I	151	NORFORK, VA	INNER CITY	81.6	418914	182706	32194
			URBAN FRINGE	217.4	249345	108750	19163
I	152	NORWALK, CONN	INNER CITY	22.0	79192	48782	4245
			URBAN FRINGE	20.0	27515	16949	1475
I	153	ODESSA, TX	INNER CITY	18.4	78380	44214	14848
			URBAN FRINGE	6.6	3265	1842	619
I	154	OGDEN, UT	INNER CITY	21.0	69485	36053	10410
			URBAN FRINGE	40.8	80242	41635	12022
I	155	OKLAHOMA CITY, OK	INNER CITY	339.0	579788	327223	97514
I	156	OMAHA, IOWA	INNER CITY	76.6	347388	166945	30668
			URBAN FRINGE	74.4	143396	68914	12660
I	157	ORLANDO, FL	INNER CITY	27.5	98965	66361	12316
			URBAN FRINGE	104.5	206514	138496	25700
I	158	OSHKOSH, KY	INNER CITY	13.0	55400	27962	10097
I	159	OWENSBORO, KY	INNER CITY	8.5	50317	26353	7522
			URBAN FRINGE	3.5	2816	1475	421
I	160	OXNARD, CA	INNER CITY	70.0	162773	84111	17343
			URBAN FRINGE	42.0	61000	42310	8724
I	161	PENSACOLA, FL	INNER CITY	24.0	59571	30929	6396
			URBAN FRINGE	42.0	107048	55578	11493
I	162	PEORIA, IL	INNER CITY	37.4	126964	64330	12482
			URBAN FRINGE	69.6	120158	60881	11813
I	163	PETERSBURG, VA	INNER CITY	8.0	36103	15811	3255
			URBAN FRINGE	34.0	64514	26824	5817
I	164	PHILADELPHIA, PA	INNER CITY	128.5	1948609	941871	143927
			URBAN FRINGE	623.5	2072457	1001734	153073
I	165	PHOENIX, ARIZ	INNER CITY	248.0	581600	327709	97127
			URBAN FRINGE	140.0	281757	158759	47053
I	166	PINE BLUFF, AR	INNER CITY	16.1	57295	22549	7790
			URBAN FRINGE	4.9	3612	1422	491
I	167	PITTSBURG, PA	INNER CITY	55.0	520167	252889	38630
			URBAN FRINGE	541.0	1325075	644599	98465
I	168	PITTSFIELD, MASS	INNER CITY	.4	57124	28162	3296
			URBAN FRINGE	3.6	5748	2834	332
I	169	PORT ARTHUR, TX	INNER CITY	48.2	57380	28378	7998
			URBAN FRINGE	24.8	59094	29226	8237

TABLE 32 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	170	PORTLAND, MAINE	INNER CITY	21.6	65116	33144	9377
			URBAN FRINGE	34.4	41483	21115	5974
1	171	PORTLAND, OR	INNER CITY	89.0	381077	218013	48948
			URBAN FRINGE	170.0	443049	252936	86786
1	172	PROVIDENCE, RI	INNER CITY	61.8	339824	187923	26778
			URBAN FRINGE	182.2	455487	251884	35892
1	173	PROVO, UT	INNER CITY	36.2	78082	32426	13269
			URBAN FRINGE	20.8	25228	10371	4244
1	174	PUEBLO, CO	INNER CITY	22.5	97453	49325	16908
			URBAN FRINGE	9.5	5847	2959	1014
1	175	RACINE, WI	INNER CITY	13.1	95193	44549	5862
			URBAN FRINGE	14.9	22215	10396	1368
1	176	RALEIGH, NC	INNER CITY	44.9	121128	69701	16841
			URBAN FRINGE	26.1	31161	17931	4333
1	177	READING, PA	INNER CITY	10.0	87621	41726	6374
			URBAN FRINGE	31.0	80311	38244	5842
1	178	RENO, NEV	INNER CITY	30.3	72863	46260	14678
			URBAN FRINGE	7.7	26824	17030	5403
1	179	RICHMOND, VA	INNER CITY	60.3	249621	123947	24024
			URBAN FRINGE	85.3	166942	82893	16067
1	180	ROANOKE, VA	INNER CITY	26.6	92115	49512	11062
			URBAN FRINGE	39.4	64506	34672	7747
1	181	ROCHESTER, MN	INNER CITY	13.4	53766	26252	8703
			URBAN FRINGE	1.6	2838	1306	301
1	182	ROCHESTER, NY	INNER CITY	36.7	296233	131147	18376
			URBAN FRINGE	109.3	305128	135005	18928
1	183	ROCKFORD, IL	INNER CITY	34.2	147205	75891	11891
			URBAN FRINGE	26.8	58079	30355	4756
1	184	SACRAMENTO, CA	INNER CITY	93.8	254364	131411	34433
			URBAN FRINGE	150.2	379368	195991	51355
1	185	SAGINAW, MI	INNER CITY	17.3	91820	43597	7927
			URBAN FRINGE	26.7	55732	26451	4812
1	186	ST. JOSEPH, MO	INNER CITY	28.7	72907	31733	9574
			URBAN FRINGE	3.3	4236	1842	856
1	187	ST. LOUIS, MO	INNER CITY	61.2	622236	290570	42740
			URBAN FRINGE	399.8	1260708	588738	86595
1	188	ST. PETERSBURG, FL	INNER CITY	55.4	216067	137089	20634
			URBAN FRINGE	105.6	279092	177077	26653
1	189	SALEM, OR	INNER CITY	24.6	68249	39423	7097
			URBAN FRINGE	12.4	24792	14321	2578

TABLE 32 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	190	SALINAS,CA	INNER CITY	13.3	58896	28674	6729
			URBAN FRINGE	1.7	3560	1733	407
1	191	SALT LAKE CITY,UT	INNER CITY	89.3	175813	91247	26337
			URBAN FRINGE	124.7	303529	187531	45469
1	192	SAN ANGELO,TX	INNER CITY	34.0	63884	33821	11664
1	193	SAN ANTONIO,TX	INNER CITY	184.0	654289	307364	68677
			URBAN FRINGE	39.0	118224	55538	12409
1	194	SAN BERNARDINO,CA	INNER CITY	116.0	244163	123078	44334
			URBAN FRINGE	194.0	339434	171102	61632
1	195	SAN DIEGO,CA	INNER CITY	317.0	696566	368132	70058
			URBAN FRINGE	64.0	501757	263015	50465
1	196	SAN FRANCISCO,CA	INNER CITY	114.0	1143713	582407	105806
			URBAN FRINGE	567.0	1044137	939078	170604
1	197	SAN JOSE,CA	INNER CITY	136.0	446504	246514	44669
			URBAN FRINGE	141.0	578769	319538	57901
1	198	SANTA BARBARA,CA	INNER CITY	21.0	70211	36959	7604
			URBAN FRINGE	16.0	59563	31354	6450
1	199	SANTA ROSA,CA	INNER CITY	20.0	49873	27871	8746
			URBAN FRINGE	18.0	25210	14088	4421
1	200	SAVANNAH,GA	INNER CITY	27.0	118344	59147	11069
			URBAN FRINGE	37.0	45409	22695	4247
1	201	SCRANTON,PA	INNER CITY	25.7	103494	60647	10298
			URBAN FRINGE	72.3	100711	59017	10021
1	202	SEASIDE,CA	INNER CITY	16.9	62251	30307	7112
			URBAN FRINGE	7.1	31033	15109	3545
1	203	SEATTLE,WA	INNER CITY	113.0	584622	305528	70916
			URBAN FRINGE	300.0	653485	341516	79269
1	204	SHERMAN,TX	INNER CITY	19.1	29079	16705	5895
			URBAN FRINGE	15.9	26264	15036	5324
1	205	SHREVEPORT,LA	INNER CITY	57.0	182208	80203	30988
			URBAN FRINGE	37.0	52284	23005	8888
1	206	SIMI VALLEY,CA	INNER CITY	23.0	56676	29287	6039
			URBAN FRINGE	2.0	260	134	28
1	207	SIOUX CITY,IOWA	INNER CITY	52.0	85925	42327	11338
			URBAN FRINGE	8.0	10012	4932	1321
1	208	SIOUX FALLS,SD	INNER CITY	2.5	7248	39028	9974
			URBAN FRINGE	2.0	2658	1431	366
1	209	SOUTH BEND,IN	INNER CITY	29.2	125802	57040	11139
			URBAN FRINGE	73.8	162770	73002	14411
1	210	SPOKANE,WA	INNER CITY	50.8	170516	89295	26367
			URBAN FRINGE	27.2	59104	30951	9139

TABLE 32 (Continued)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
1	211	SPRINGFIELD, IL	INNER CITY	28.2	91607	47820	10069
			URBAN FRINGE	8.8	29107	15236	3208
1	212	SPRINGFIELD, MO	INNER CITY	61.5	119999	56800	19004
			URBAN FRINGE	1.5	1341	635	213
1	213	SPRINGFIELD, OH	INNER CITY	16.7	81850	48258	6692
			URBAN FRINGE	8.3	11803	6526	965
1	214	SPRINGFIELD, MASS	INNER CITY	86.3	280594	138333	16190
			URBAN FRINGE	151.7	233714	115221	13485
1	215	STAMFORD, CONN	INNER CITY	38.1	108853	67053	5835
			URBAN FRINGE	31.9	76045	46843	4076
1	216	STEUBENVILLE, OH	INNER CITY	27.2	58028	27217	4722
			URBAN FRINGE	11.8	27464	12082	2235
1	217	STOCKTON, CA	INNER CITY	29.9	107459	52478	10199
			URBAN FRINGE	17.1	52914	25841	8961
1	218	SYRACUSE, NY	INNER CITY	25.8	197270	83652	13563
			URBAN FRINGE	70.2	178899	75862	12300
1	219	TACOMA, WA	INNER CITY	47.7	154565	75814	20397
			URBAN FRINGE	81.3	177966	86952	23466
1	220	TALLAHASSEE, FL	INNER CITY	26.1	71934	37572	7164
			URBAN FRINGE	3.9	5919	3092	589
1	221	TAMPA, FL	INNER CITY	84.5	277736	176217	26523
			URBAN FRINGE	46.5	91006	57741	8691
1	222	TERRE HAUTE, IN	INNER CITY	26.1	70316	29331	9766
			URBAN FRINGE	5.9	10592	4418	1471
1	223	TEXARKANA, TX	INNER CITY	16.2	30497	14594	5710
			URBAN FRINGE	14.8	20073	13434	5256
1	224	TEXAS CITY, TX	INNER CITY	83.0	84054	40531	9290
1	225	TOLEDO, OH	INNER CITY	81.2	384015	207234	30515
			URBAN FRINGE	84.8	103774	56002	8246
1	226	TOPEKA, KANS	INNER CITY	47.5	124938	68940	19686
			URBAN FRINGE	5.5	7170	3956	1130
1	227	TRENTON, NJ	INNER CITY	7.5	104578	54590	6076
			URBAN FRINGE	57.5	169570	88516	9852
1	228	TUCSON, ARIZ	INNER CITY	80.0	262933	150768	42120
			URBAN FRINGE	25.0	31251	17920	5006
1	229	TULSA, OK	INNER CITY	172.0	331800	186269	58093
			URBAN FRINGE	8.0	39699	22287	7047
1	230	TUSCALOOSA, AL	INNER CITY	27.4	65773	30424	7365
			URBAN FRINGE	16.6	20102	9298	2251
1	231	TYLER, TX	INNER CITY	23.1	57770	30038	9819
			URBAN FRINGE	1.9	2011	1043	342

TABLE 32 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	INNER CITY / URBAN FRINGE	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
I	232	UTICA, NY	INNER CITY	16.0	91654	36340	6194
			URBAN FRINGE	59.0	88701	35169	5994
I	233	VINELAND, NJ	INNER CITY	69.5	47643	24870	2768
			URBAN FRINGE	15.5	25936	13539	1507
I	234	WACO, TX	INNER CITY	58.7	95326	49294	14516
			URBAN FRINGE	31.3	23517	12161	3381
I	235	WASHINGTON, DC	INNER CITY	61.4	756516	264024	21258
			URBAN FRINGE	433.6	1724973	602016	40472
I	236	WATERBURY, CONN	INNER CITY	27.6	108033	66548	5791
			URBAN FRINGE	32.4	48953	30155	2624
I	237	WATERLOO, IOWA	INNER CITY	59.2	75578	38693	8361
			URBAN FRINGE	9.8	37303	19097	4127
I	238	WEST PALM BEACH, FL	INNER CITY	38.4	57328	38623	5394
			URBAN FRINGE	97.6	230233	155111	21663
I	239	WHEELING, WV	INNER CITY	13.3	48280	20804	4022
			URBAN FRINGE	14.7	44664	19320	3720
I	240	WICHITA, KANS	INNER CITY	86.5	276699	163334	42821
			URBAN FRINGE	18.5	25635	15132	3967
I	241	WICHITA FALLS, TX	INNER CITY	42.0	97564	55811	14980
I	242	WILKES, PA	INNER CITY	6.7	58817	34467	5852
			URBAN FRINGE	76.3	164013	96117	16319
I	243	WILMINGTON, DEL	INNER CITY	12.9	80306	41077	8042
			URBAN FRINGE	97.1	290081	140640	31997
I	244	WILMINGTON, NC	INNER CITY	17.5	46169	25389	5422
			URBAN FRINGE	11.5	11476	6311	1348
I	245	WINSTON, NC	INNER CITY	56.5	132901	76770	15124
			URBAN FRINGE	9.5	9683	5593	1102
I	246	WORCESTER, MASS	INNER CITY	37.4	176603	87065	10190
			URBAN FRINGE	46.6	70813	34911	4086
I	247	YORK, PA	INNER CITY	5.3	50355	23724	3624
			URBAN FRINGE	31.7	72771	34298	5239
I	248	YOUNGSTOWN, OH	INNER CITY	45.6	203174	112421	13196
			URBAN FRINGE	83.4	192366	106441	12494

Source: U.S. Census Bureau (1973) and U.S. Federal Highway Administration (1978).

TABLE 33. EXPOSURE/DOSAGE ANALYSIS DATA BASE FOR TYPE II CITY AREA SOURCES

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	1	ANNISTON,AL	16.1	31588	16899	3693
2	2	BESSEMER,AL	14.4	33484	17937	3266
2	3	DECATUR,AL	26.6	38044	20277	6467
2	4	DOTHAN,AL	49.0	36733	19579	6245
2	5	FLORENCE,AL	32.4	53911	29989	8270
2	6	PHENIX CITY,AL	19.9	25281	13475	4298
2	7	SELMA,AL	13.2	27379	14593	4654
2	8	ANCHORAGE,AL	16.2	48157	22206	8525
2	9	FLAGSTAFF,AR	64.1	26117	12327	4701
2	10	YUMA,AR	7.9	29007	13691	5221
2	11	EL DORADO,AR	16.0	25203	10821	5360
2	12	FAYETTEVILLE,AR	18.1	30639	13358	6252
2	13	HOTSPRING,AR	23.4	35631	15250	7584
2	14	JONESBORO,AR	12.0	27026	11567	5730
2	15	WEST MEMPHIS,AR	8.7	25929	11098	5497
2	16	ANTIOCH,CA	7.4	28005	15023	2771
2	17	CONCORD,CA	25.8	85067	45635	8416
2	18	CORONA,CA	23.2	27506	14211	3588
2	19	FAIRFIELD,CA	15.4	44146	21550	4667
2	20	LANCASTER,CA	14.5	32570	17517	2816
2	21	LIVERMORE,CA	11.9	37703	18098	3589
2	22	LODI,CA	7.1	28691	14011	4859
2	23	LOMPOC,CA	9.9	25320	13328	2742
2	24	NAPA,CA	13.1	35978	19138	5280
2	25	NEWARK,CA	8.4	27151	13609	2584
2	26	NOVATO,CA	20.5	30833	17731	2496
2	27	OCEANSIDE,CA	35.2	40491	21225	4072
2	28	REDLANDS,CA	21.8	36414	18834	7928
2	29	REDWOOD CITY,CA	20.5	55539	33006	5561
2	30	SAN LUIS OBISPO,CA	9.1	28036	14971	3701
2	31	SAN RAFAEL,CA	14.3	38949	22398	3153
2	32	SANTA CRUZ,CA	12.2	32076	18781	4874
2	33	SANTA MARIA,CA	14.3	32749	17239	3547
2	34	VISALIA,CA	12.4	27268	14561	3599
2	35	WALNUT CREEK,CA	14.7	39833	21369	3941
2	36	FORT COLLINS,CO	10.8	43368	25370	8630
2	37	GREELEY,CO	7.7	38902	22758	7741
2	38	MIDDLETOWN,CON	44.0	36903	22732	1978
2	39	MILFORD,CON	22.3	50858	31329	2726
2	40	NEW LONDON,CON	6.1	31606	19469	1694

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	41	NORWICH,CON	26.1	41433	25823	2221
2	42	SHELTON,CON	30.8	27194	16752	1458
2	43	TORRINGTON,CON	39.6	31952	19682	1713
2	44	DAYTONA BEACH,FL	22.8	45327	17628	4629
2	45	FORT MYERS,FL	12.0	27351	18190	3526
2	46	FORT PIERCE,FL	10.6	29728	17064	2567
2	47	KEY WEST,FL	4.1	27323	15683	3279
2	48	LAKELAND,FL	12.6	41550	24952	6462
2	49	MELBOURNE,FL	23.9	40312	25846	3537
2	50	MERRITT ISLAND,FL	16.2	29233	18743	2565
2	51	PANAMA CITY,FL	13.8	32125	18440	3055
2	52	POMPANO BEACH,FL	11.5	37711	26300	3224
2	53	SARASOTA,FL	14.0	40237	31313	4538
2	54	TITUSVILLE,FL	15.2	30515	19568	2678
2	55	ATHENS,GA	14.7	44342	23191	6518
2	56	ROME,GA	13.5	30756	16085	4521
2	57	VALDOSTA,GA	11.1	32502	16996	4778
2	58	WARNER ROBINS,GA	15.5	33430	19004	3309
2	59	HILO,HA	56.1	26359	12626	2167
2	60	IDAHO FALLS,ID	9.4	35776	18317	11019
2	61	LEWISTON,ID	15.1	26068	13347	8209
2	62	POCATELLO,ID	13.7	40036	20498	12331
2	63	ALTON,IL	11.0	39700	19493	4009
2	64	BELLEVILLE,IL	9.6	41908	20577	4316
2	65	DANVILLE,IL	12.9	42690	20961	4397
2	66	DE KALB,IL	3.4	32928	16168	3392
2	67	EAST ST. LOUIS,IL	13.9	69947	34344	7205
2	68	FREEPORT,IL	8.3	27736	13618	2857
2	69	GALESBURG,IL	12.2	36290	17818	3738
2	70	KANKAKEE,IL	7.6	30886	15165	3181
2	71	PEKIN,IL	9.1	31297	15806	2674
2	72	QUINCY,IL	11.9	45208	22236	4665
2	73	BLOOMINGTON,IN	8.4	42776	21388	6416
2	74	COLUMBUS,IN	8.7	27295	13648	4094
2	75	ELKHART,IN	15.6	43594	21797	6539
2	76	KOKOMO,IN	9.2	44042	22021	6606
2	77	MARION,IN	9.6	39836	19918	5975
2	78	MICHIGAN,IN	20.6	39273	19639	5891
2	79	NEW ALBANY,IN	11.3	38402	19201	5760
2	80	RICHMOND,IN	13.7	44010	22005	6602

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	81	AMES, IA	16.8	39699	22033	8218
2	82	BURLINGTON, IA	13.0	32444	18006	6716
2	83	CLINTON, IA	33.1	34719	19269	7187
2	84	FORT DODGE, IA	14.5	31263	17351	6471
2	85	IOWA CITY, IA	21.1	46850	26002	9698
2	86	MARSHALLTOWN, IA	14.6	26366	14633	5458
2	87	MASON CITY, IA	15.2	30491	16923	6312
2	88	OTTUMWA, IA	11.9	29695	16401	6147
2	89	HUTCHINSON, KA	13.4	36885	20508	9406
2	90	LAWRENCE, KA	16.7	45588	25342	11623
2	91	LEAVENWORTH, KA	8.9	25147	13982	6412
2	92	MANHATTAN, KA	7.4	27555	15321	7027
2	93	OVERLAND PARK, KA	46.2	76868	42739	19601
2	94	PRAIRIE VILLAGE, KA	6.3	28104	15626	7167
2	95	SALINA, KA	15.8	37714	20969	9617
2	96	BOWLING GREEN, KE	16.2	36253	18272	6598
2	97	FORT KNOX, KE	20.2	37502	18901	6825
2	98	PADUCAH, KE	11.9	31627	15940	8756
2	99	ALEXANDRIA, LA	12.0	41507	18263	7056
2	100	BOSSIER CITY, LA	21.1	41750	18370	7098
2	101	HOUMA, LA	8.5	30893	13593	5252
2	102	KENNER, LA	14.2	29910	13160	5885
2	103	NEW IBERIA, LA	7.5	30147	13265	5125
2	104	BANGOR, ME	34.3	33168	16883	4776
2	105	ANNAPOLIS, MD	5.8	29592	15006	2409
2	106	CUMBERLAND, MD	8.0	29820	15387	2639
2	107	HAGERSTOWN, MD	8.5	35862	18505	3174
2	108	ATTLEBORO, MASS	27.0	32907	16223	1899
2	109	GLOUCESTER, MASS	24.7	27937	13773	1612
2	110	MARLBOROUGH, MASS	20.5	27936	13772	1612
2	111	TAUNTON, MASS	47.0	43756	21572	2525
2	112	BATTLECREEK, MICH	11.8	38931	19708	3988
2	113	HOLLAND, MICH	13.8	26337	13669	2818
2	114	MIDLAND, MICH	24.9	35206	18272	3767
2	115	PORT HURON, MICH	7.5	35829	16509	3537
2	116	YPSILANTI, MICH	4.1	29502	14129	2129
2	117	AUSTIN, MN	7.3	25031	13091	4300
2	118	MANKATO, MN	9.8	30895	16158	8407
2	119	ST. CLOUD, MN	10.8	39691	16453	5501
2	120	WINONA, MN	13.0	26303	13798	4617

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	121	COLUMBUS,MI	8.3	25795	11350	4488
2	122	GREENVILLE,MI	8.0	39648	17445	6099
2	123	HATTIESBURG,MI	17.5	38274	16841	6660
2	124	MERIDIAN,MI	25.4	45083	19837	7844
2	125	PASCAGOULA,MI	14.9	27471	12087	4700
2	126	VICKSBURG,MI	10.5	25506	11258	4452
2	127	CAPE GIRARDEAU,MO	18.5	30918	14439	4576
2	128	FERGUSON,MO	5.8	28837	14944	1514
2	129	FLORISSANT,MO	9.0	66006	34207	3465
2	130	FORT LEONARDWOOD,MO	12.2	33848	15807	5010
2	131	JEFFERSON CITY,MO	18.8	32250	15061	4773
2	132	JOPLIN,MO	28.7	39227	18319	5806
2	133	KIRKWOOD,MO	8.9	31880	16521	1674
2	134	RAYTOWN,MO	10.0	33635	15569	2762
2	135	ST. CHARLES,MO	9.5	31834	18741	3063
2	136	MISSOULA,MT	7.9	29403	15290	9527
2	137	GRAND ISLAND,NE	11.1	31269	16635	7017
2	138	CONCORD,NH	63.3	30022	16212	3032
2	139	PORTSMOUTH,NH	15.2	26188	14142	2645
2	140	LONG BRANCH,NJ	5.1	31774	16586	1846
2	141	NEW BRUNSWICK,NJ	8.6	41855	21848	2432
2	142	OLD BRIDGE,NJ	6.0	25176	13142	1463
2	143	PERTH AMBOY,NJ	4.7	38777	20242	2263
2	144	SAYREVILLE,NJ	16.2	32508	16969	1889
2	145	CLOVIS,NM	11.4	28553	14505	7110
2	146	HOBBS,NM	16.6	26109	13263	6501
2	147	LAS CRUCES,NM	17.8	37857	19231	9426
2	148	ROSWELL,,NM	24.2	33908	17225	8443
2	149	SANTA FE,NM	29.4	41167	20913	10251
2	150	AMSTERDAM,NY	5.8	25524	10800	1705
2	151	AUBURN,NY	8.5	34599	12871	1754
2	152	ELMIRA,NY	7.3	39945	17068	2751
2	153	ITHACA,NY	8.6	26226	9756	1330
2	154	JAMESTOWN,NY	9.5	39795	14804	2018
2	155	KINGSTON,NY	7.7	25544	9502	1295
2	156	NEWBURGH,NY	3.9	26219	9753	1329
2	157	NIAGARA FALLS,NY	13.4	85615	37243	4828
2	158	NORTH TONAWANDA,NY	10.0	36012	15666	1905
2	159	POUGHKEEPSIE,NY	4.8	33029	15809	1792
2	160	WATERTOWN,NY	9.2	30787	11453	1561

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	161	BURLINGTON,NC	15.2	36198	21194	4314
2	162	CAMP LEJEUNE,NC	16.4	34517	18950	5592
2	163	CHAPEL HILL,NC	7.8	25541	14213	4138
2	164	GASTONIA,NC	19.9	47153	24006	5079
2	165	GOLDSBORO,NC	9.0	26821	14725	4345
2	166	GREENVILLE,NC	11.4	29078	15964	4710
2	167	KANNAPOLIS,NC	29.9	36236	19894	6070
2	168	ROCKY MOUNT,NC	12.4	34315	18839	5589
2	169	WILSON,NC	8.1	29347	16116	4754
2	170	BISMARCK,ND	10.9	34670	18098	12273
2	171	GRAND FORKS,ND	9.2	39044	20381	13822
2	172	MINOT,ND	8.1	32270	16845	11424
2	173	ALLIANCE,OH	6.2	26547	13975	1835
2	174	AUSTINTOWN,OH	8.2	29363	15457	1698
2	175	BOARDMAN,OH	9.5	30060	16245	1784
2	176	FAIRBORN,OH	7.5	32279	18659	2918
2	177	FINDLAY,OH	11.4	35800	15278	3210
2	178	LANCASTER,OH	13.1	32911	19517	3724
2	179	MARION,OH	7.1	30681	22358	3497
2	180	MASSILON,OH	8.9	32600	18843	2947
2	181	NEWARK,OH	13.3	41822	29173	3781
2	182	PORTSMOUTH,OH	12.2	27633	15972	2498
2	183	SANDUSKY,OH	9.1	32674	18862	2954
2	184	XENIA,OH	6.0	25373	14666	2294
2	185	ZANESVILLE,OH	8.1	33045	19110	2987
2	186	BARLESVILLE,OK	9.3	29672	25606	11644
2	187	ENID,OK	23.5	44548	24145	11493
2	188	MUSKOGEE,OK	22.5	37331	20233	9631
2	189	PONCA,OK	18.7	25940	14059	3627
2	190	SHAWNEE,OK	32.5	25131	13570	8929
2	191	STILLWATER,OK	17.3	31126	16870	8031
2	192	CORVALLIS,OR	7.9	35153	20740	5414
2	193	MEDFORD,OR	12.2	28454	16788	4382
2	194	LEBANON,PA	4.6	28572	16743	2843
2	195	NEW CASTLE,PA	7.7	38559	22596	3837
2	196	STATE COLLEGE,PA	4.3	33778	19794	3361
2	197	WILLIAMSPORT,PA	9.1	37918	18132	2770
2	198	NEWPORT,RI	7.3	34562	19113	2723
2	199	WOONSOCKET,RI	7.9	46820	25891	3609
2	200	ANDERSON,SC	10.8	27556	13585	3553

TABLE 33 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	201	FLORENCE,SC	9.8	25997	12817	3354
2	202	ROCK HILL,SC	14.1	33846	16686	4366
2	203	SPARTANBURG,SC	16.3	44546	21472	4421
2	204	ABERDEEN,SD	5.6	26476	13264	7652
2	205	RAPID CITY,SD	16.5	43836	21962	12669
2	206	CLARKSVILLE,TN	25.8	31719	12803	3216
2	207	JACKSON,TN	17.3	39996	20438	6159
2	208	JOHNSON CITY,TN	15.6	33770	14829	4144
2	209	KINGSPORT,TN	17.4	31920	12563	3802
2	210	MURFREESBORO,TN	11.5	26360	13067	3316
2	211	OAK RIDGE,TN	82.7	28384	18884	3271
2	212	BIG SPRING,TX	12.8	28024	15190	5505
2	213	DENTON,TX	27.6	39874	19274	6035
2	214	FORT HOOD,TX	8.2	32677	13629	3868
2	215	KILLEEN,TX	26.0	35507	14009	4204
2	216	KINGSVILLE,TX	10.8	28605	15075	5464
2	217	LONGVIEW,TX	22.6	45588	24021	8706
2	218	MESQUITE,TX	25.8	55209	31552	6336
2	219	RICHARDSON,TX	28.0	48662	24243	8245
2	220	TEMPLE,TX	22.6	33431	13943	3958
2	221	VICTORIA,TX	16.6	41349	21791	7898
2	222	BURLINGTON,VT	10.1	38633	19819	4945
2	223	CHARLOTTESVILLE,VA	10.4	38880	21348	4160
2	224	DANVILLE,VA	16.7	46391	23799	5938
2	225	BELLINGHAM,WA	20.8	39379	21580	7718
2	226	BREMERTON,WA	9.8	35307	19348	6920
2	227	FORT LEWIS,WA	13.8	38053	18592	5017
2	228	LAKES DISTRICT,WA	15.8	48149	23525	6349
2	229	LONGVIEW,WA	11.1	28373	15548	5561
2	230	RICHLAND,WA	23.1	26283	11413	3330
2	231	YAKIMA,WA	11.4	45588	24369	9680
2	232	FAIRMONT,WV	8.7	25919	10808	4017
2	233	MORGANTOWN,WV	6.7	29387	12254	4555
2	234	PARKERSBURG,WV	10.9	44198	18921	4058
2	235	BELOIT,WI	12.8	35729	17043	3480
2	236	EAU CLAIRE,WI	19.9	44603	21276	4344
2	237	FONDDULAC,WI	9.4	35698	17028	3477
2	238	JANESVILLE,WI	19.0	46426	22145	4522
2	239	MANITOWOC,WI	11.0	33497	15978	3263
2	240	SHEBOYGAN,WI	9.6	48525	23146	4726

TABLE 33 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
2	241	WAUSAU, WI	11.9	32806	15648	3198
2	242	CASPER, WY	8.2	39406	21670	14847
2	243	CHEYENNE, WY	11.4	40063	22434	15364

Sources: U.S. Census Bureau (1973) and U.S. Federal Highway Administration (1978).

TABLE 34. EXPOSURE/DOSAGE ANALYSIS DATA BASE FOR TYPE III CITY AREA SOURCES

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
3	1	ARAB,AL.	6.1	4399	3467	921
3	2	BAY MINETTE,AL.	7.4	6727	3665	1295
3	3	IRONDALE,AL.	3.1	3166	1616	309
3	4	CONWAY,AR	8.8	15510	6638	3208
3	5	ENGLAND,AR	1.7	3075	1316	652
3	6	LAKE VILLAGE,AR	2.0	3310	1417	702
3	7	MENA,AR	5.2	4530	1939	960
3	8	MONTICELLO,AR	3.1	5005	2176	1078
3	9	RUSSELLVILLE,AR	7.0	11750	5029	2491
3	10	WALNUT RIDGE,AR	2.3	3800	1626	806
3	11	ALTURAS,CA	2.4	2799	1520	369
3	12	BANNING,CA	14.3	12034	6217	1570
3	13	CARMEL VALLEY,CA	7.4	3026	1561	366
3	14	CHINA LAKE,CA	7.6	11105	5503	2047
3	15	CUCAMONGA,CA	3.5	5796	2960	1261
3	16	EUREKA,CA	14.9	24337	13215	3212
3	17	GRIDLEY,CA	1.0	3534	1919	466
3	18	LAMONT,CA	1.6	7007	3472	1292
3	19	NEWHALL,CA	4.0	9651	5191	835
3	20	PALMDALE,CA	47.4	8511	4578	736
3	21	SANTA MARIA,CA	2.4	7129	3753	772
3	22	SUISAN CITY,CA	1.3	2917	1424	308
3	23	BRIGHTON,CO	2.7	8309	4806	1587
3	24	GOLDEN,CO	5.5	9817	6348	1559
3	25	DANIELSON,CN	1.1	4588	2821	245
3	26	ORANGETOWN,CN	17.4	13524	8331	725
3	27	SIMSBURY CENTER,CN	4.5	4994	3076	268
3	28	WILLIMANTIC,CN	4.5	14402	8872	772
3	29	MEMPHIS,FL	1.5	3207	1841	385
3	30	MIAMI SHORES,FL	2.4	9425	5410	1131
3	31	PERRY,FL	9.8	7701	4420	924
3	32	CARROLLTON,GA	10.5	13520	7071	1987
3	33	LARKSTON,GA	.6	3127	1627	219
3	34	SMYRNATOWN,GA	9.2	19157	12470	2460
3	35	HALEIWA,HAW	1.8	2626	1257	216
3	36	CHUBBUCK,ID	6.0	2924	1520	900
3	37	ALSIP,IL	8.0	11141	4512	346
3	38	CENTREVILLE,IL	4.1	11378	5587	1172
3	39	CHESTER,IL	7.0	5310	2607	547
3	40	CLARENDON HILLS,IL	1.5	6750	3600	358

TABLE 30 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
3	41	EFFINGHAM, IL	3.2	9458	4644	974
3	42	HENRY, IL	1.0	2610	1201	269
3	43	LA GRANGE PARK, IL	2.3	15459	6260	400
3	44	LAWRENCEVILLE, IL	2.0	5863	2879	604
3	45	LYONS, IL	1.9	11124	4505	345
3	46	SPARTA, IL	1.5	4307	2115	444
3	47	AURORA, IN	2.5	4293	2147	322
3	48	AUSTIN, IN	2.1	4902	2451	368
3	49	HOBART, IN	15.0	21485	9106	1330
3	50	DENISON, IA	5.5	6218	3451	1287
3	51	ELDORA, IA	4.4	3223	1789	667
3	52	MOUNT VERNON, IA	1.2	3018	1675	625
3	53	ONAWA, IA	4.5	3154	1750	653
3	54	WINTERSET, IA	1.3	3654	2028	756
3	55	CONCORDIA, KA	2.9	7221	4015	1041
3	56	MULVANE, KA	1.0	3185	1801	454
3	57	PHILLPSBURG, KA	1.2	3241	1802	826
3	58	DAWSON SPRING, KN	3.7	3009	1517	548
3	59	FORT WRIGHT, KN	2.1	4819	2429	877
3	60	JENKINS, KN	6.5	2552	1206	464
3	61	OKOLONA, KN	7.1	17643	9166	1306
3	62	CARIBOU, ME	8.2	10419	5303	1500
3	63	FARMINGTON, ME	2.9	3096	1876	445
3	64	KITTERY CENTER, ME	2.4	7363	3748	1060
3	65	BAINBRIDGE, MD	1.9	5257	2713	465
3	66	PALMER PARK, MD	.8	8172	4217	676
3	67	DUXBURYTOWN, MASS	23.3	7636	3765	441
3	68	GREENFIELDTOWN, MASS	21.8	18116	8931	1045
3	69	HADLEYTOWN, MASS	23.2	3750	1849	216
3	70	ORANGE CENTER, MASS	2.5	3847	1897	222
3	71	TEMPLETONTOWN, MASS	31.9	5863	2090	338
3	72	WARETOWN, MASS	34.2	8187	4036	472
3	73	WILMINGTONTOWN, MASS	17.2	17102	8431	987
3	74	FREMONT, MICH	2.6	3465	1798	371
3	75	GAYLORD, MICH	2.1	3012	1563	322
3	76	GROSSE ILE, MICH	7.9	8306	3945	404
3	77	LEVEL PARK, MICH	1.9	3000	1559	316
3	78	ST. LOUIS, MICH	1.8	4101	2128	439
3	79	LAKE CITY, MN	3.3	3954	1808	629
3	80	MINNETRISTA, MN	26.1	2878	1514	203

TABLE 34 (Continued)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
3	81	MORA,MN	3.8	2882	1350	482
3	82	MACON,MISS	3.5	2612	1149	454
3	83	MORTON,MISS	2.8	2672	1176	465
3	84	AVA,MISS	2.2	2504	1169	371
3	85	BUTLER,MISS	2.3	3984	1861	590
3	86	DEXTER,MISS	3.5	6024	2813	892
3	87	CENTRAL CITY,NE	1.7	2883	1941	701
3	88	EXETERTOWN,NH	20.0	8892	4802	898
3	89	HAMPTONTOWN,NH	13.3	8011	4326	437
3	90	HILLSBOROUGHTOWN,NH	44.5	2775	1499	181
3	91	HINSDALETOWN,NH	20.5	3276	1769	331
3	92	NEWMARKET COMPACT,N	2.1	2645	1428	267
3	93	WOLFEBOROTOWN,NH	47.4	3036	1639	307
3	94	DUMONT,NJ	1.8	20155	10521	1171
3	95	KENDALL PARK,NJ	2.8	7412	3869	431
3	96	LITTLE SILVER,NJ	2.8	6010	3137	349
3	97	MOORESTOWN,NJ	7.1	14179	7397	823
3	98	NEW MILFORD,NJ	2.3	19149	9996	1113
3	99	NORTH CAPE MAY,NJ	.7	3812	1990	221
3	100	ELMA CENTER,NY	5.4	2784	1130	114
3	101	LAKE CARMEL,NY	1.7	4796	1784	243
3	102	LITTLE FALLS,NY	4.1	7629	3812	530
3	103	NEWMARK,NY	5.0	11644	5241	1318
3	104	NEW YORK MILLS,NY	.9	3805	1511	248
3	105	NORTH BELLPORT,NY	3.3	5903	2922	283
3	106	NORTH MASSAPEQUA,NY	2.8	23123	12350	642
3	107	RYE,NY	5.6	15869	7933	454
3	108	SCOTIA,NY	1.8	7370	3469	379
3	109	TICONDEROGA,NY	1.4	3268	1216	166
3	110	VOORHEESVILLE,NY	2.2	2826	1159	159
3	111	KERNSVILLE,NC	3.0	4815	2923	575
3	112	NEW RIVER-GIEGER,NC	7.3	8699	4776	1409
3	113	STANFORD,NC	4.4	11716	6432	1898
3	114	BRUNSWICK,OH	10.7	15852	9276	1476
3	115	GREENSVILLE,OH	1.3	6092	3521	551
3	116	NEW PHILADELPHIA,OH	4.4	15184	8776	1373
3	117	ADA,OK	6.5	14859	8854	3834
3	118	LINDSAY,OK	1.3	3705	2008	956
3	119	SULPHUR,OK	3.3	5158	2796	1331
3	120	BLAKELY,PA	4.0	6391	3071	469

TABLE 34 (Concluded)

CITY TYPE	CITY CODE	CITY NAME	LAND AREA (SQ MILES)	1970 POPULATION (PERSON)	1973 AUTO	1973 TRUCK
3	121	DOYLESTOWN,PA	3.0	8270	3791	879
3	122	GETTYSBURG,PA	2.0	7275	3379	816
3	123	LIBERTY,PA	1.5	3594	1761	269
3	124	ST. CLAIR,PA	1.3	4576	2062	455
3	125	SLIPPERY ROCK,PA	1.7	4949	2900	492
3	126	TYRONE,PA	1.6	7072	3300	816
3	127	VANDERGRIFT,PA	1.3	7889	3777	877
3	128	WEST WARWICKTOWN,RI	8.3	24323	13451	1917
3	129	CAPEHART,SC	1.8	4490	2214	879
3	130	CONWAY,SC	5.2	8151	4018	1081
3	131	MOBRIDGE,SD	1.5	4545	2277	1314
3	132	LA FOLLETTE,TN	2.0	6902	3527	1063
3	133	ROCKWOOD,TN	3.5	5259	2687	810
3	134	BURNET,TX	3.6	2064	1509	847
3	135	CROWLEY,TX	6.3	2662	1509	358
3	136	FRONIA,TX	1.3	3111	1639	894
3	137	LOCKHART,TX	4.3	6489	3420	1239
3	138	LULING,TX	2.4	4719	2487	901
3	139	PORTLAND,TX	3.8	7302	3872	912
3	140	SAN AUGUSTINE,TX	4.7	2539	1338	488
3	141	SEALY,TX	1.8	2685	1415	813
3	142	SILSBEE,TX	8.0	7271	3163	1816
3	143	PRICE,UT	1.9	6218	3068	1380
3	144	RADFORD,VI	8.0	11596	6366	1241
3	145	LYDEN,WA	1.4	2088	1539	850
3	146	STEILACOOM,WA	1.7	2050	1392	376
3	147	HARTLAND,WI	2.4	2763	1434	206
3	148	MEDFORD,WI	2.2	3454	1648	336
3	149	SOUTH MILWAUKEE,WI	4.7	23297	10025	814
3	150	GREEN RIVER,WY	4.3	4196	2304	1578

Source: U.S. Census Bureau (1973) and U.S. Federal Highway Administration (1978).

SECTION 4

UNCERTAINTIES

The data and data-based estimations described in Sections 2 and 3 are subject to uncertainties that may be evaluated subjectively or objectively. Quantification of uncertainty has been undertaken where feasible. If data for the quantification of some aspects of uncertainty were not available within the scope of this program, an effort was made to subjectively describe the parameters of the uncertainty factor and evaluate its qualitative effect.

Review of uncertainty is presented in two parts:

> Uncertainty of Emissions Estimation
> Uncertainty of Exposure/Dosage Estimation.

UNCERTAINTIES INVOLVED IN EMISSION ESTIMATIONS

A number of factors could cause the estimated emissions of a specific chemical to be considerably higher or lower than the actual amount calculated. This is true to a greater degree for individual plant sites and to a lesser degree for total industry sources. The primary factors that could cause emission estimate deviations are listed and discussed below:

> A primary source of error would occur if production or use quantities were estimated too high or too low. The effect on emissions and, in turn, on ambient concentrations would be directly proportional.

- Not all plants operate at the same level of capacity. By distributing total production of a chemical based on the ratio of individual site capacity compared to total industry capacity, error is automatically built in. Plants that operate below the average industry level of capacity would have emissions estimated too low. This type of averaging necessarily leads to underestimates of the exposure and dosage at the highest concentration levels; in fact, the averaging will lead to underestimates of the maximum concentrations. Depending on population patterns, however, the effect on total dosage may be relatively little.
- The omission of significant sources of emissions in any summary for a specific chemical would render the total emissions estimate too low.
- The use and efficiency of control devices is not uniform for all producers or users of a specific chemical. Emission factors derived from a plant without control devices would make emissions estimates from those plants that do use control devices too high. Conversely, if the emissions factor were derived from a plant with an effective control device, the emissions estimates from those plants not employing a similar device would be too low.
- In general, old plants have greater associated emissions than do new plants producing or using the same chemical. Emission factors derived primarily from old plant data would cause emissions estimates to be too high, and emissions factors derived primarily from modern, new plants would cause emissions estimates to be too low.
- Emissions estimates derived by assuming that all the chemical is lost to the atmosphere when it is used in solvent applications are probably too high. Some portion of most solvents normally is disposed of by encapsulation for burial or is burned for the heat value of the solvent.

There is a level of uncertainty or confidence associated with each source identified and each emissions estimate. Although that level cannot be quantified, it can be assumed to vary as a function of the quality of the available information on sources and emissions. Uncertainty levels were defined according to this rationale, as shown in Table 37. It should be noted that emissions uncertainty levels 1, 2, 3, and 4 correspond with levels A, B, C, and D, respectively, used in the individual chemical emissions summaries. These defined uncertainty levels are necessarily subjective. They were assigned by HI on the basis of the nature of data used to identify the sources and generate the emissions estimates. Even with the highest level of confidence (level 1), attempts to quantify the uncertainty would represent a formidable task. A complete listing of the levels of uncertainty assigned to the emissions of the 35 chemicals from the production, use, and incidental sources is shown as Table 38. A composite uncertainty, based on emissions-weighted averages of the component uncertainties, is also presented for each chemical.

UNCERTAINTIES IN EXPOSURE/DOSAGE ESTIMATIONS

Estimating human exposure to toxic chemicals requires detailed knowledge of both population distribution and concentration patterns over the surface of the earth within a given time period. The ideal estimate would require error-free characterizations of concentrations, $c(\bar{x},t)$,at all spatial coordinates $\bar{x}$ and times t and, similarly, of population densities, $p(\bar{x},t)$, for all $\bar{x}$ and t. At each instant t, the total dosage would be given by

$$D(t) = \int c(\bar{x},t)\ p(\bar{x},t)\ d\bar{x} \qquad (31)$$

and the exposure at level L by

TABLE 35. DEFINITION OF UNCERTAINTY LEVELS IN CHEMICAL SOURCE LOCATIONS AND EMISSIONS ESTIMATIONS

Uncertainty Type	Uncertainty Level	Definition	Example
Sources	1	Complete data of reasonable accuracy on site locations and individual site capacities.	Complete data on ethylene oxide-producing locations are available along with total industry and individual plant capacities to allow for the distribution of total industry production.
	2	Partially estimated data of indeterminate accuracy on site locations or individual site capacities.	Complete data on peracetic acid-producing locations are available but total use of acetaldehyde to produce peracetic acid must be distributed evenly over all sites because total and individual site capacity data are not available.
	3	Complete data of indeterminate accuracy on regional site locations using an average production or use quantity per site.	Complete data on regional locations of phenolic resin plants are available and an average use of phenol per site can be determined.
	4	Site locations and production or use quantities of indeterminate accuracy estimated without data.	The total number of quaternary ammonium comcompound-producing locations was estimated, and total benzyl chloride usage to produce it was evenly distributed over the estimated sites.
	5	Unable to identify site locations.	Site locations for miscellaneous uses of phenol could not be identified.
Emissions	1	Emissions estimated from company site visit data of reasonable accuracy.	Emissions data were obtained from site visits by HI personnel to various companies (i.e., chlorobenzene production emission factor).
	2	Emissions estimated from data of indeterminate accuracy supplied by a company to state agencies.	Emissions data were obtained from various state agencies emissions inventory questionnaires (i.e., phosgene emissions factor from its use to produce TDI).
	3	Emissions estimated from data of indeterminate accuracy obtained from other published sources.	Emissions data were obtained from other previously published emissions information (i.e. pentaerythritol formaldehyde use emissions factor).
	4	Emissions of indeterminate accuracy estimated without data.	Emissions data and emissions estimates made by HI personnel (i.e., mixed xylene emissions factor from ethyl benzene production).

Source: Hydroscience, Incorporated, Knoxville, Tennessee.

TABLE 36. LEVELS OF UNCERTAINTY FOR ASSESSED CHEMICALS

Chemical	Source Location	Emissions Estimates
Acetaldehyde	1.2*	2.6*
Production	1	2
Use		
Acetic acid	1	2/3
Peracetic acid	2	2
Pentaerythritol	1	3
Pyridenes	1	3
Glyoxal	2	4
1,3-butylene glycol	2	2
Miscellaneous	5	4
Acrolein	1.3*	1.8*
Production	1	1
Use		
Acrylic acid and esters	1	1
Glycerin	1	1
Methionine	2	4
Miscellaneous	5	4
Allyl Chloride	1.0*	2.0*
Production	1	2
Use		
Epichlorohydrin	1	2
Benzyl Chloride	1.6*	2.8*
Production	1	2/3
Use		
Butyl benzyl phthalate	2	3
Quarternary ammonium compounds	2	4
Benzyl alcohol	1	3
Miscellaneous	5	4

---

* Composite level of uncertainty based on weighted average of total emissions.

Source: Hydroscience, Incorporated, Knoxville, Tennessee estimates.

TABLE 36 (Continued)

Chemical	Source Location	Emissions Estimates
Beryllium	4.9*	3.0*
Production	5	3
Use		
Beryllium alloy	2	3
Beryllium fabrication	5	3
Beryllium oxide	5	3
Incidental		
Gray iron foundries	4	3
Coal burning	3/5	3
Oil burning	3/5	3
Carbon Tetrachloride	4.7*	4.0*
Production	1	1
Use		
Solvents	4	4
Nitrochlorobenzene	1	3
DDT	1	3
Diphenyl oxide	2	2
Miscellaneous	5	4
Chloroform	4.8*	3.9*
Production	1	1
Use		
Fluorocarbons	1	1
Solvents, miscellaneous	5	4
Chlorprene	2.0*	2.0*
Production	2	2
Use		
Neoprene	2	2

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 36 (Continued)

Chemical	Source Location	Emissions Estimates
Cresols (m-, o-, p- isomers)	4.7*	3.9*
Production	1/2	2/4
Use		
BHT/antioxidants	1/2	4
Phenolic resins	4	4
Pesticides	3	3
Pyrethroid pesticides	4	4
TCP production	1	3
Solvent	3	3
Disinfectant/cleaning	5	4
Ore flotation	4	4
Miscellaneous	5	4
Incidental		
Coke ovens	3	3
Dichlorobenzenes (o- and p- isomers)	4.8*	3.9*
Production	1	1
Use		
3,4-Dichloroaniline	2	3
Toluene diisocyanate solvent	1	4
Miscellaneous solvents	5	4
Dye manufacturing	5	4
Pesticide intermediates	5	4
Space deodorant	5	4
Moth control	5	4
Dimethylamine	2.2*	3.3*
Production	2	3
Use		
Dimethyl formide	2	4
Lauryl dimethylamine oxide	2	4
Rubber chemical accelerators	4	4
Dimethyl hydrazine/pesticides	4	4

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 36 (Continued)

Chemical	Source Location	Emissions Estimates
2,3,7,8-TCDD (Dioxin)	4.3*	3.3*
Incidental		
Trichlorophenol	2	4
2,4,5-T	2	3
Pentachlorophenol	1	4
Burning	5	3
Application of 2,4,5-T	5	1
Application of pentachlorophenol	5	4
Epichlorohydrin	2.2*	2.3*
Production	1	2
Use		
Glycerin	1	2
Epoxy resins	2	2
Miscellaneous	5	4
Elastomers	5	4
Ethylene Oxide	1.0*	1.0*
Production	1	1
Use		
All	1	1
Formaldehyde	1.7*	3.7*
Production	1	1
Use		
Resins	1	4
Butanediol	1	4
Pentaerythritol	1	3
Hexamethylene tetramine	1	3
Trimethylopropane	1	2
Miscellaneous	5	4

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 38 (Continued)

Chemical	Source Location	Emissions Estimates
Nickel	3.8*	3.0*
Production	1	3
Use		
All	3	3
Incidental		
Power plants	3	3
Boilers	5	3
Coke ovens	3	3
Diesel fuel	5	3
Nitrobenzene	3.9*	3.9*
Production	1	1
Use		
Aniline	1	1
Solvent	4	4
Chemical intermediates	4	3
PCBs	2.0*	4.0*
Incidental		
Incinerators	2	4
Phenol	1.2*	2.2*
Production	1	3
Use		
Caprolactam	1	1
Bisphenol A	1	3
Nonylphenol	1	3
Salicylic acid	1	3
Dodecyl phenol	1	4
Phenolic resins	1	4
Adipic acid	1	1
Miscellaneous	5	4

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 36 (Continued)

Chemical	Source Location	Emissions Estimates
Hexachlorocyclopentadiene	4.0*	4.0*
Production	4	4
Use		
Pesticides	4	3
Flame retardants	4	4
Resins	4	4
Manganese	4.0*	3.0*
Production	5	3
Use		
All	3	3
Incidental		
All	3/5	3
Methylene Chloride	4.5*	3.7*
Production	1	1
Use		
Solvents	3	3/4
Miscellaneous	5	4
Morpholine	4.7*	4.0*
Production	2	1
Use		
Rubber chemicals	3	4
Corrosion inhibitor	5	4
Optical brightener	4	4
Polishes and waxes	4	4
Miscellaneous	5	4

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 36 (Continued)

Chemical	Source Location	Emissions Estimates
Phosgene	1.0*	2.0*
Production	1	2
Use		
TDI	1	2
MDI	1	2
Polycarbonates	5	4
Miscellaneous	5	4
Propylene Oxide	1.0*	2.0*
Production	1	2
Use		
Urethane polyols	1	2
Propylene glycol	1	2
Surfactant polyols	2	4
di/tri-Propylene glycols	1	2
Glycol ethers	2	2
Miscellaneous	5	4
Toluene	3.7*	3.4*
Production	1	1/2/4
Use		
Benzene	1	2
Solvent	5	4
TDI	1	3
Xylenes	1	4
Benzoic acid	1	3
Benzyl chloride	1	3
Vinyl toluene	1	4
Benzaldehyde	2	4
p-Cresol	1	4
Miscellaneous	5	4
Incidental		
Gasoline marketing	3	3

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 36 (Continued)

Chemical	Source Location	Emissions Estimates
Toluene (Continued)		
Incidental		
Gasoline - automobiles	3	3
Gasoline - exhaust	3	3
Coke ovens	3	3
Trichloroethylene	3.1*	3.0*
Production	1	2
Use		
Vapor degreasing	3	3
Solvent	5	4
1,1,1-Trichloroethane	3.6*	3.3*
Production	1	2
Use		
Degreasing	3	3
Chemical intermediate	5	4
Aerosols	5	4
Solvent	5	4
Xylenes (o-, m-, and p- isomers)	4.0*	3.5*
Production		
Catalytic reformate	1	2
Pyrolysis gasoline	1	1
Coal-derived	1	4
Styrene by-product	2	4
Use		
p-Xylene isomer	1	2
o-Xylene isomer	1	4
m-Xylene isomer	1	2
Ethyl benzene	1	4
Solvent	5	4

---

* Composite level of uncertainty based on weighted average of total emissions.

TABLE 36 (Concluded)

Chemical	Source Location	Emissions Estimates
Xylenes (Continued)		
Use		
Phthalic anhydride	1	3
Terephthalic acid	1	3
Dimethyl terephthalate	1	1
Isophthalic acid	1	1
Incidental		
Gasoline marketing	3	3
Gasoline evaporation - automobiles	3	3
Gasoline exhaust - automobiles	3	3

---

* Composite level of uncertainty based on weighted average of total emissions.

$$E_L(t) = \int_{\Omega_L(t)} p(\bar{x},t)\,dx \qquad (32)$$

where

$$\Omega_L(t) = \{\bar{x} \mid c(\bar{x},t) > L\} \quad .$$

Certain statistics, such as maxima, minima, quantiles, and means could then be derived over a time period from the functions $D(t)$ and $E_L(t)$.

There are various ways in which the estimates obtained in the Human Exposure Project may differ from this idealized computation. Although many of the error components can be analyzed quantitatively, such analysis requires gathering extensive statistics on the population and concentration patterns, a task that is well beyond the resources available to us in this project. The discussion is therefore mostly qualitative. Below, we identify the major error sources.

Sources of Error

Population Count Errors--

The population distribution data base used for the exposure computations is derived from 1970 census counts. These counts are carefully prepared by the Bureau of the Census, but at best are only very accurate estimates. The Bureau has admitted suspicions that in some areas of the country the counts may be too low by significant amounts. However, no comprehensive analysis exists on the degree and distribution of undercounting over the entire United States.

Apart from these suspected undercounts, Minimax found discrepancies between counts in different census data sets. .The net difference over the United States is extremely small (0.017 percent) and is probably negligible compared to the undercounting errors. The effect of these population count errors is that exposure and dosage estimates for some regions are too low.

Concentration Pattern Errors--

The concentration patterns used in the exposure computations are obtained through atmospheric dispersion modeling based on known source characteristics and weather patterns at nearby stations. Naturally, any deviations in these estimates from the true pattern directly affect the exposure results.

Additional considerations pertain to concentration pattern estimates for sources not analyzed individually. No statistical data are available on the geographical distribution of sources analyzed by prototype. It is, therefore, very difficult to estimate the exact concentration levels for populations exposed to emissions from more than one such source. The exposure data derived from prototype modeling were based on the assumptions that all sources modeled are isolated sources and that the population in the urban areas exposed to emissions from one source would not be exposed to those from other sources. This assumption is obviously not true everywhere. For example, the total nubmer of trichloroethylene-using open top vapor degreasers in the United States was estimated by HI to be 6,110, and the total land area in urbanized areas is 100,190 km^2, on the average. Therefore, most of the urban population is likely to be exposed to emissions from multiple degreasers; thus, the computations may overestimate the number of people exposed to some concentration but underestimate the dosage received by some individuals. However, for a population in the vicinity of a "major" source (an OTVD or a CVD), the impacts from other sources would be insignificant compared to that from the nearby major source. One might conclude that the exposure estimates are conservative estimates and that the exposure data for the higher concentration levles are more accurate than those for the lower concentration levels. However, the total dosage estimates would not be influenced by the geographical distribution of sources.

Uncertainties in exposure-dosage estimates made with the box model method for area sources include uncertainties of the emissions estimates described in HI's final report, the census population uncertainties as described in Minimax's final report, and uncertainties directly attributable to this method. The last-mentioned uncertainties include the following:

- > Dispersion factors.
  - Representativeness of mean annual wind for the state to each city.
  - Representativeness of neutral atmospheric stability as a long-term mean condition.
- > Time factors.
  - The use of annual average emissions and meteorology.
  - The estimation of 1978 population vehicle totals from data of earlier years.
- > Spatial factors.
  - The use of the Hanna-Gifford model that provides no spatial resolution of concentration patterns.
  - The assumption that population and vehicle density patterns did not change from data base years to 1978.

The effect of each of these factors is to reduce a spectrum of concentration or emissions values (i.e., a set of values ranging from maximum to minimum) to a single, mean value for each city. This may not affect total dosages, but it will lead to underestimation of exposure at high concentrations and overestimation of low concentration exposures.

If the concentration patterns are congruous with the source patterns, time variations of emissions or meteorology would have little effect, because the annual average doses or exposures would average out high and low concentrations in the same proportion at every station. There will, however, be locations where people receive higher or lower exposure-dosage than the mean, even on an annual average basis. Thus, spatial variability appears to be a more significant factor than time variability. The study team explored the possibility of developing a population spectrum as a function of exposure level within individual cities, based on the census population data and land area of all census tracts of a set of representative cities.

Discretizing Errors

Certain errors are introduced into the exposure calculations because each concentration pattern is described by an array of concentrations at only 160 points in the vicinity of the source instead of a continuous function. Similarly, the population distribution is described by a series of "point masses" located at the population centroids of all 1970 census ED/BG. Particularly in less densely populated regions, in which ED/BGs cover relatively large areas, the latter practice may introduce population displacements over sizable distances. Thus, the fractional error is most likely to be large where exposure-dosages are small because of low population density.

We have grouped both of these error sources under the heading of "Discretizing Errors," because both results from replacing continuous functions with discrete approximations for the purpose of reducing the associated computational burden.

Interpolation Error--

Unfortunately, the discrete patterns generated for concentrations and populations generally do not coincide. The exposure program uses interpolation techniques for either of two purposes:

- > Compute a concentration value at each ED/BG centroid.
- > Apportion the population of each ED/BG among several concentration grid points.

The first technique is used far from the source, where centroids are more densely concentrated than grid points. The second technique is applied near the source, where grid points are more dense than centroids.

Both methods introduce interpolation errors, the severity of which depends on the degree of variability in the concentration and population patterns.

Location Errors--

The relationships between concentrations and populations depend on the accuracy with which the source and ED/BG centroid coordinates are known. Source coordinates are supplied in degrees, minutes, and seconds. For a source in Houston, Texas, for example, a second of longitude represents about 27 meters and a second of latitude represents about 31 meters. ED/BG coordinates are given in degrees to four decimal places. At Houston, .0001 degree of lontitude represents about 11 meters. These figures represent lower bounds on the locational errors, based solely on the precision of the numbers.

We have little information on the actual measurement error in these coordinates. The census documentation we received contained no mention of measurement errors.

In the MED-X validation work, an attempt was made to estimate ED/BG location accuracy by testing whether each ED/BG fell within its corresponding county boundary. About 5.6 percent of the ED/BGs failed the test; only 0.42 percent fell more than 2 km from their county boundaries. Most of these failures are probably due to causes other than centroid location errors, such as concavities in ED/BG boundaries, digitizing errors in the county boundaries, and county boundary changes since 1970. The large amount of "noise" present precluded drawing more definite quantitative estimates from the validation study.

Commuting Pattern Errors--

There are also time-dependent aspects of the exposure problem. The exposure program uses a time-averaged concentration pattern for each source, so that the time dimension is ignored in the computations. If the population distribution were essentially constant over the averaging time period, the resulting estimates would be true averages. However, population distributions are constantly changing as people commute to work, go shopping, and take longer trips. Particularly in urban industrial centers, the shifts in populations and concentrations throughout the day may be highly correlated; thus, the actual exposure may differ considerably from the value obtained by matching time-averaged concentrations with population distributions based on census addresses. Whether the exposure is over- or underestimated depends on whether populations in the vicinity of a source are drained (e.g., because people leave residences near the source for work in an urban center) or are augmented (e.g., because of employment near the source).

A quantitative estimate of this source of error would require a detailed study of commuting patterns for each major SMSA.

Population Growth and Migration Errors--

The final source of error considered here arises from the age of the population estimates, which are based on the 1970 census. Migration and suburban development since April 1970 have affected population distributions around certain sources. The Human Exposure Program does take into account county-level changes in population from 1970 to 1978, but otherwise it leaves the intra-county distributions unaffected. As in the case of commuting patterns, errors arising from migration patterns can be quantified only through detailed studies of the affected regions.

A Simple Model of the Discretizing Error--

Although a full characterization of the uncertainties in the exposure estimates is a very complex job, certain important properties of some of these error sources can be derived from simplified mathematical models.

To analyze the discretizing error with a simple one-dimensional, time-independent model, let c(x) be the concentration and p(x) the population density per unit length. Dosage is given by

$$D = \int c(x)p(x)\,dx \quad . \qquad (33)$$

The discretizing error involves replacing the concentration c(x) with the constant $c(x_0)$ over some ED/BG with centroid at x_0. The Taylor formula for c(x) about x_0 is

$$c(x) = c(x_0) + c'(x_0)\,(x-x_0) + 1/2c''(t_x)\,(x-x_0)^2 \quad , \qquad (34)$$

where t_x is between x and x_0 and depends on x. Then, for this ED/BG,

$$D = \int c(x)p(x)\,dx = c(x_0)P + c'(x_0)\int (x-x_0)p(x)\,dx$$

$$+ 1/2\int c''(t_x)\,(x-x_0)^2\,p(x)\,dx \quad , \qquad (35)$$

where P is the total ED/BG population. The second term is zero, by the definition of x_0 as the population centroid. The third term is the discretizing error in dosage made by computing dosage as the product of the concentration at the centroid and the total population. For a typical concentration pattern, $c''(x)$ is negative along a radial direction near the source and positive farther away. The error term changes sign in the same fashion. This suggests that "discretizing" the concentration pattern leads to a systematic underestimation of dosages at low concentrations and overestimating dosages at high concentrations. The size of the error depends on the value of $c''(x)$ and is, therefore, dependent on the relative locations of sources and ED/BG centroids.

Sensitivity Analysis of Location Errors--

To assess the effect of location errors on exposures and dosages, we reran the computations for Denka Chemical Corporation in Houston, Texas, for the eight possible shifts in the source location obtained by changing the source location by one minute of latitude, longitude, or both, in either direction (N/S or E/W, respectively). Selected results from these runs are shown in Tables 37 and 38. Note that a minute of latitude represents about 1.9 km and a minute of longitude represents about 1.6 km at

TABLE 37. PERCENTAGE OF CHANGE IN DOSAGE FROM BASE CASE RESULTING FROM LOCATION SHIFT

	Changes							
Latitude Shift	+1'	-1'	0	0	+1'	+1'	-1'	-1'
Longitude Shift	0	0	+1'	-1'	+1'	-1'	+1'	-1'
Concentration Level ppb								
10	-54	-92	210	172	71	-71	50	107
1	-44	-6	189	144	23	-75	97	119
0.1	-27	20	65	30	7	-51	48	45
.0	-15	11	40	17	12	-31	29	23
.001	-11	7	33	12	10	-26	22	15
0	-11	7	33	12	10	-26	22	15

Source: Minimax Research Corporation computations.

TABLE 38. PERCENTAGE OF CHANGE IN EXPOSURE FROM BASE CASE RESULTING FROM LOCATION SHIFT

	Changes							
Latitude Shift	+1'	-1'	0	0	+1'	+1'	-1'	-1'
Longitude Shift	0	0	+1'	-1'	+1'	-1'	+1'	-1'
Concentration Level ppb								
10	-60	-90	200	170	70	-70	50	100
1	-35	42	178	127	7	-78	114	132
0.1	-7	9	34	-20	16	-64	27	11
0.01	4	4	12	-6	21	-3	12	-4
.001	3	-4	6	-7	9	-4	1	-12
0	3	-4	6	-7	9	-4	2	-12

Source: Minimax Research Corporation computations.

Houston. These shifts produce very large variations in exposures and dosages estimated for high concentrations. At low concentrations, the dosage variations are still farily large, but exposure counts are relatively stable.

Summary

We have described seven sources of error that can affect the accuracy of the exposure results. Available information was insufficient to support any numerical estimates. Further insight has been gained by studying analytical models and carrying out sensitivity tests, but it is difficult to generalize such results to an entire group of sources.

A fruitful approach in future projects would be to select a small number of sources representing a variety of demographic settings and then to carry out detailed quantitative error analyses for each of these sources, based on information about local conditions. Such a study should provide a better understanding of the error components in human exposure estimates.

REFERENCES

Anderson, G. E., et al. (1977), "Air Quality in the Denver Metropolitan Region: 1974-2000," EPA-908/1-77-002, prepared for the U.S. Environmental Protection Agency, Region VIII, Denver, Colorado, by Systems Applications, Incorporated, San Rafael, California.

Briggs, G. A. (1975), "Lectures on Air Pollutions and Environmental Impact Analyses," American Meteorological Society, Boston, Massachusetts.

Briggs, G. A. (1973), "Diffusion Estimation for Small Emissions," Air Resources Atmospheric Turbulence and Diffusion Laboratory, National Oceanic Atmospheric Administration (NOAA), Oak Ridge, Tennessee.

Briggs, G. A. (1970), "Some Recent Analyses of Plume Rise Observations," Proc. of International Air Pollution Conference, December 1970, Washington, D.C.

Briggs, G. A. (1969), "Plume Rise," USAEC Critical Review Series, TID-25075, Clearinghouse for Federal Scientific and Technical Information.

Burt, E. W. (1977), "Valley Model User's Guide," EPA 450/2-77-018, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Busse, A. D., and J. R. Zimmerman (1973), "User's Guide for the Climatological Dispersion Model," NTIS PB-227346, National Oceanic Atmospheric Association (NOAA), Rockville, Maryland.

CEQ (1977), "Environmental Quality: The Eighth Annual Report of the Council on Environmental Quality," Washington, D.C.

Calvert, J. G., et al. (1975), "Spectroscopic Studies of Photochemical Smog Trace Pollutant Detection," Ohio State University, Columbus, Ohio.

Killus, J. P., et al. (1977), "Continued Research in Mesoscale Air Pollution Simulation Modeling: Volume V--Refinements in Numerical Analysis, Transport, Chemistry, and Pollutant Removal," EF77-142, Systems Applications, Incorporated, San Rafael, California.

Lucas, H. J. (1933), Organic Chemistry, (American Book Company, New York, New York).

Mara, S. J., and S. S. Lee (1978), "Human Exposures to Atmospheric Benzene," EPA-450/3-78-031 Report to the Environmental Protection Agency, Contract 68-01-4314, Stanford Research Institute, Menlo Park, California.

Martin, D. O., and J. A. Tikvart (1968), "A General Atmospheric Diffusion Model for Estimating the Effects on Air Quality of One or More Sources," APCA Paper, presented at the 61st annual APCA meeting, June 1968, St. Paul, Minnesota.

Mitre (1976), "Scoring Organic Air Pollutants," Technical Report 2248.

National Climatic Center (1979), "STAR Tabulations Master List," Asheville, North Carolina.

Pasquill, F. (1971), "Atmospheric Dispersion of Pollution," Q. J. R. Meteorol. Soc., Vol. 97, pp. 369-395.

Pasquill, F. (1970), "The Prediction of Diffusion over an Urban Area," Proc. of the Symposium on Multiple-Source Urban Diffusion, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

Pasquill, F. (1961), "The Estimation of the Dispersion of Windborne Material," Met. Mag., Vol. 90, pp 33-49.

Tesche, T. W., and C. S. Burton (1978), "Simulated Impact of Alternative Emissions Control Strategies on Photochemical Oxidants in Los Angeles," EF78-22R, Systems Applications, Incorporated, San Rafael, California.

Turner, D. B. (1970), Workbook of Atmospheric Dispersion Estimates, Office of Air Programs, Publication No. AP-26, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

EDF (1977), "Environmental Defense Fund Petition for the Initiation of Rulemaking Proceedings to Establish a Policy Governing the Classification and Regulation of Carcinogenic Air Pollutants Under the Clean Air Act," transmitted by letter to EPA Administrator Costle from Robert Rauch, Staff Attorney, Environmental Defense Fund, Washington, D.C.

EPA (1978), "Administration of the Toxic Substances Control Act: First Annual Report--1977," U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

EPA (1978b), *Federal Register*, Section 5565, 9 February 1978.

EPA (1977), "User's Manual for Single Source (CRSTER) Model," U.S. Environmental Protection Agency, U.S. Department of Commerce, NTIS PB-271360.

EPA (1976), "Report to U.S. EPA Specialists Conference on the EPA Modeling Guideline," Conference report organized by Argon Laboratory, 22-24 February 1977, Chicago, Illinois.

Gay, B. W., et al. (1976), "Atmospheric Oxidation of Chlorinated Ethylenes," *Environ. Sci. Technol*., Vol. 10, No. 1, p. 58.

Gifford, F. A., Jr., (1968), "An Outline of Theories of Diffusion in the Lower Layers of the Atmosphere," David H. Slade, ed., *Meteorology and Atomic Energy*.

Hanna, S. R. (1978), "Diurnal Variation of the Stability Factor in the Simple ATDL Urban Dispersion Model," *J. Air Pollut. Control Assoc.*, Vol. 28, No. 2, pp. 147-150.

Hanna, S. R., and F. A. Gifford (1973), "Modeling Urban Air Pollution," *Atmos. Environ.*, Vol. 7, pp. 131-136.

Hanna, S. R. (1973), "A Simple Dispersion Model for the Analysis of Chemically Reactive Pollutants," *Atmos. Environ.*, Vol. 7, pp. 803-817.

Hanna, S. R. (1971), "A Simple Method of Calculating Dispersion from Urban Area Sources," *J. Air Pollut. Control Assoc.*, Vol. 21, No. 12, pp. 774-777.

Hanst, P. L., J. W. Spence, and M. Miller (1977), "Atmospheric Chemistry of N-Nitroso Dimethylamine," *Environ. Sci. Technol.*, Vol. 11, No. 4, p. 403.

Turner, D. B. (1964), "A Diffusion Model for an Urban Area, Atmospheric Dispersion Estimates," 6th Printing Rev., Government Printing Office, U.S. Environmental Protection Agency, Office of Air Programs, Publ. No. AP-26, Washington, D.C.

Turner, D. B., and J. H. Novak (1978), "User's Guide for RAM," EPA-600/8-78-016a, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

U.S. Bureau of Census (1979), Statistical Abstract of the United States, 1978 (Government Printing Office, Washington, D.C.).

U.S. Bureau of Census (1978), County and City Data Book, 1977, (Government Printing Office, Washington, D.C.).

U.S. Bureau of Census (1973), County and City Data Book, 1972, (Government Printing Office, Washington, D.C.).

U.S. Federal Highway Administration (1978), "Motor Vehicle Registration," (Government Printing Office, Washington, D.C.).

U.S. Federal Highway Administration (1974), "Motor Vehicle Registrations by Standard Metropolitan Statistical Areas," (Government Printing Office, Washington, D.C.).

Wang, C. C., et al. (1975), "Hydroxyl Radical Concentrations Measured in Ambient Air," Science, Vol. 189, p. 797.